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THE PRODUCTION ENGINEER

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

SEPTEMBER 1961

THE PRODUCTION ENGINEER

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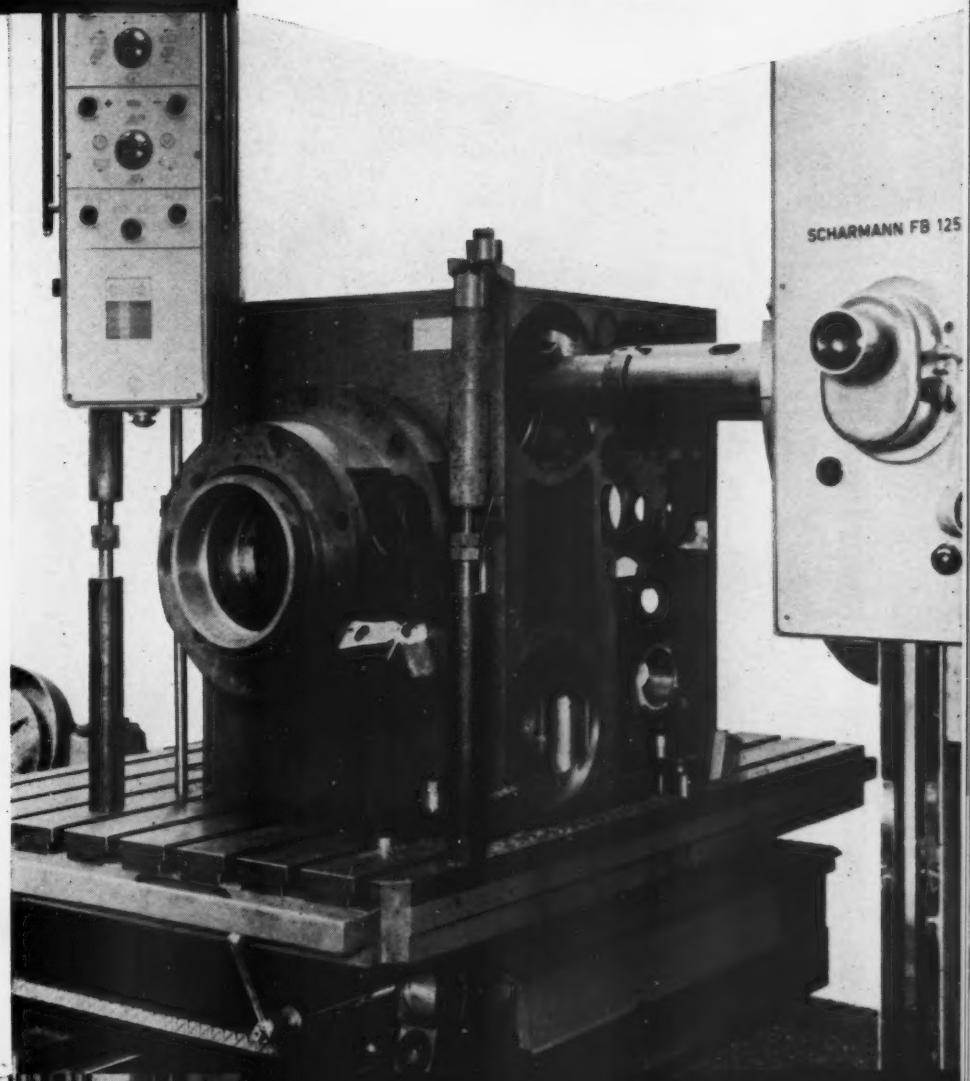

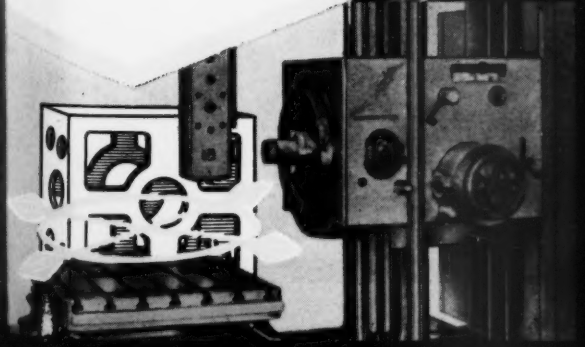

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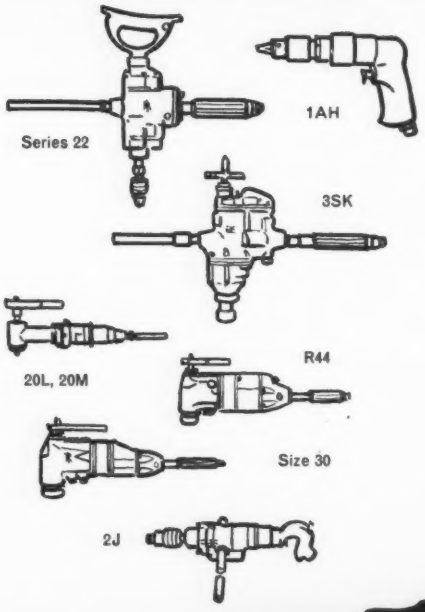

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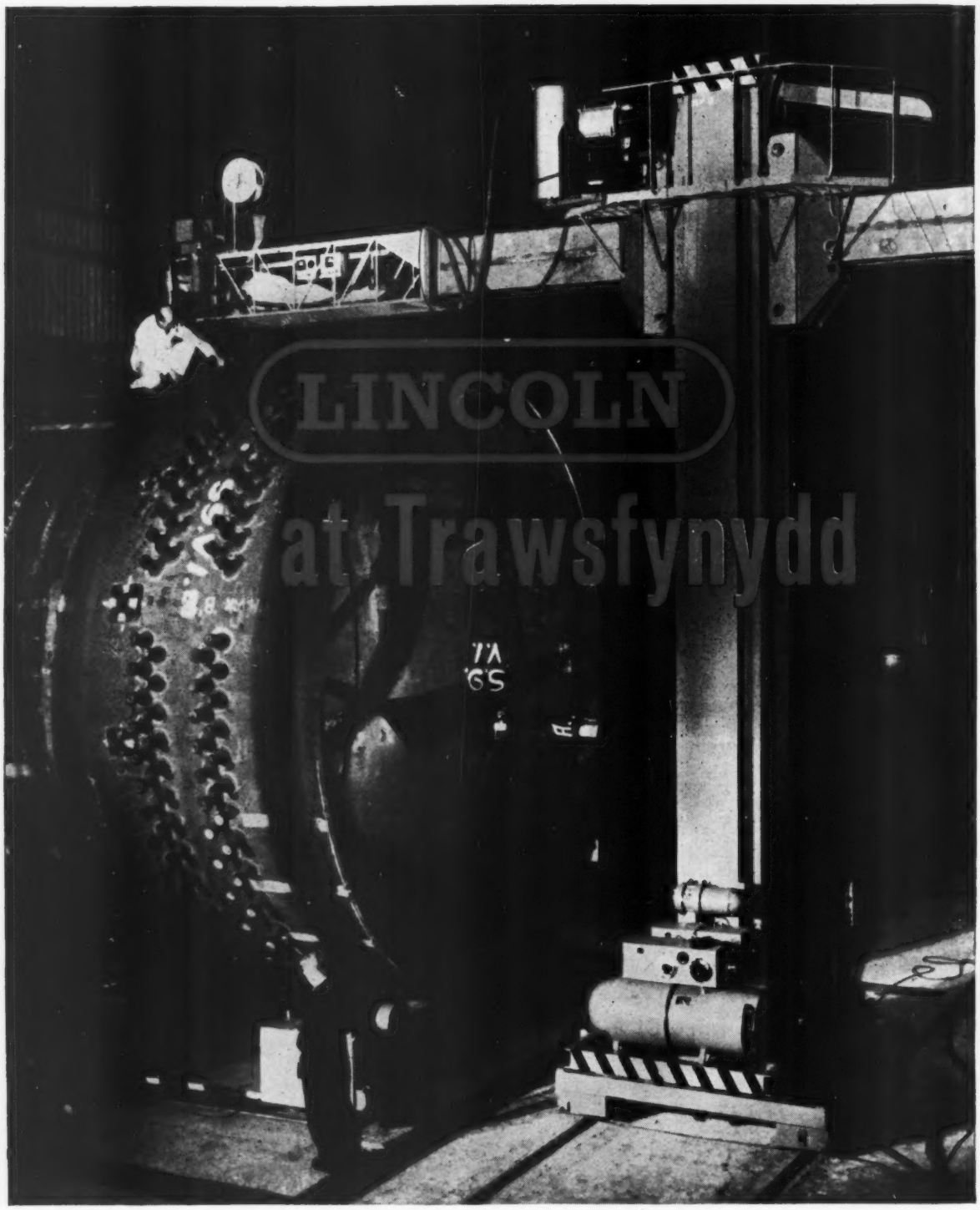

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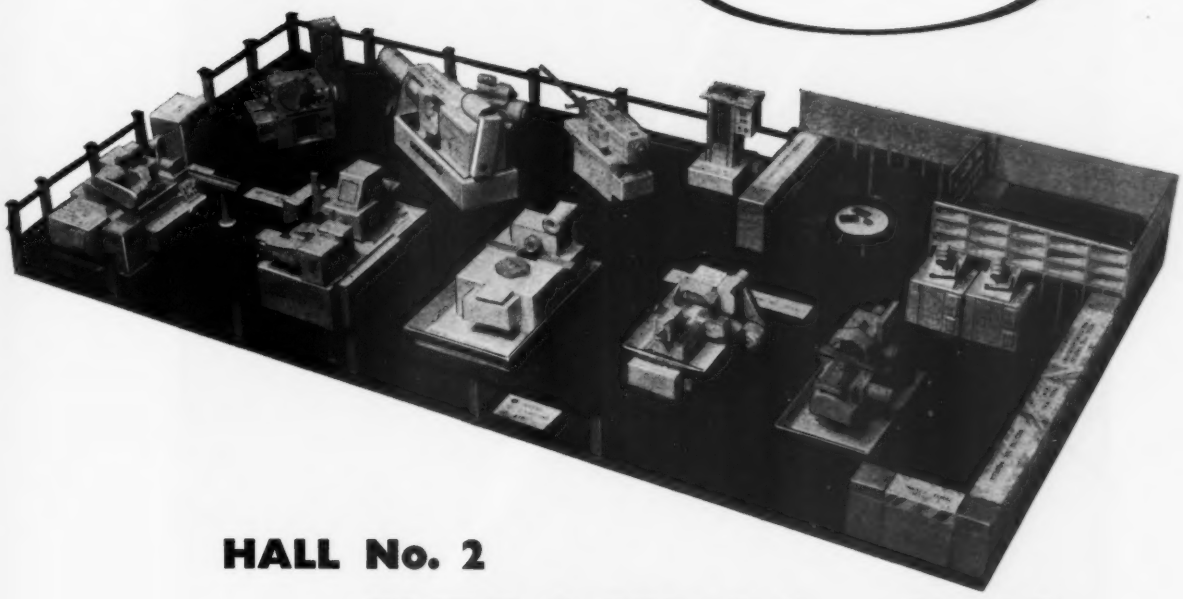

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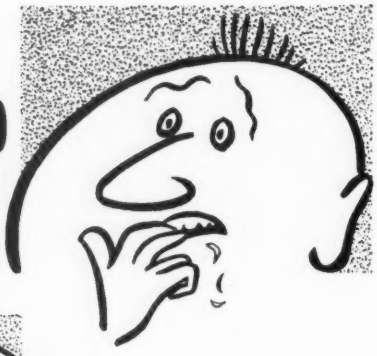

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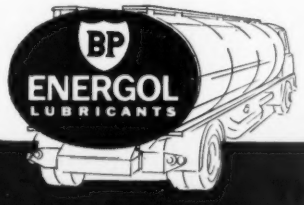

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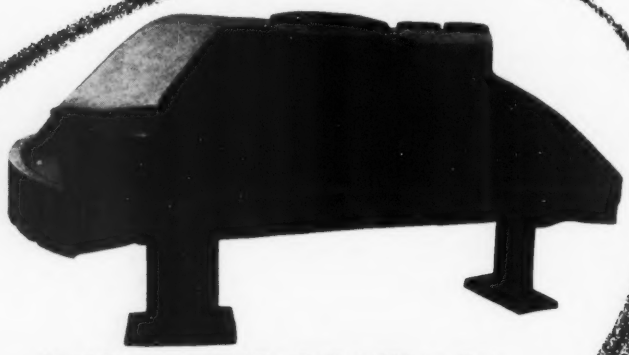

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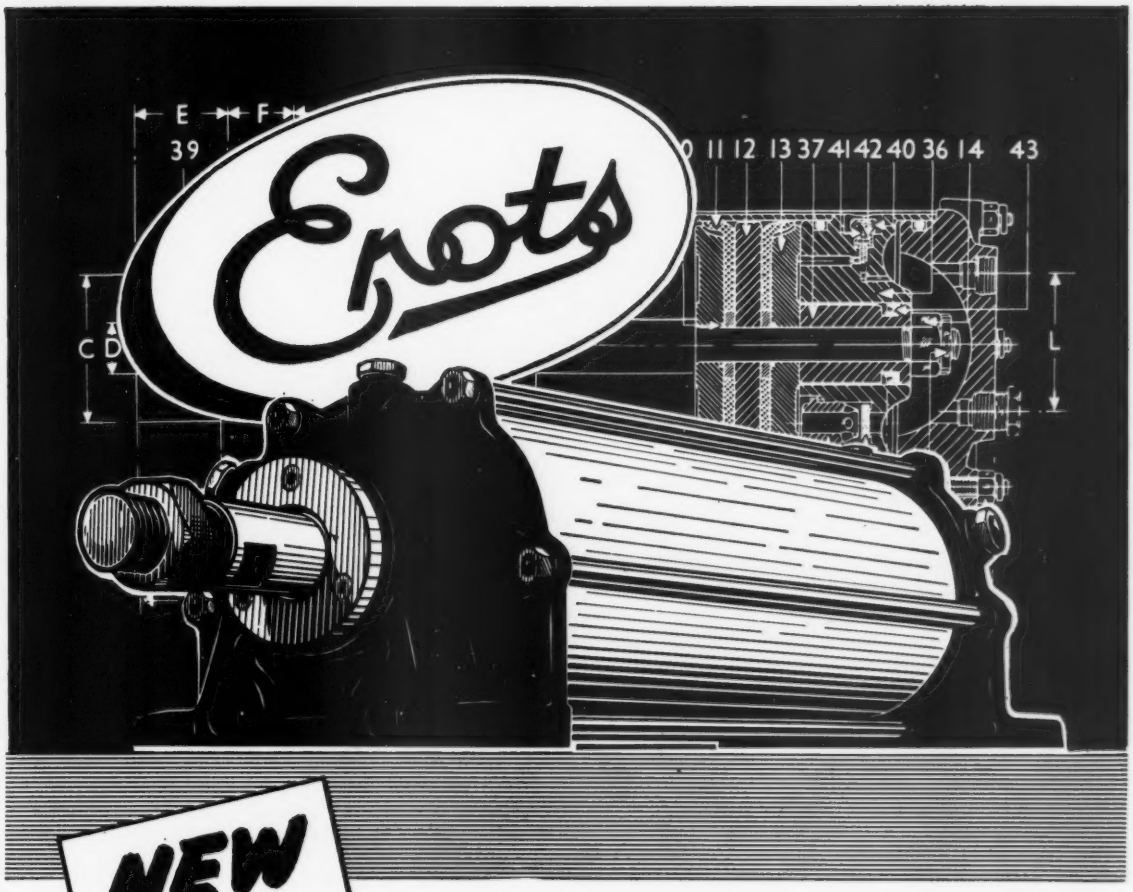

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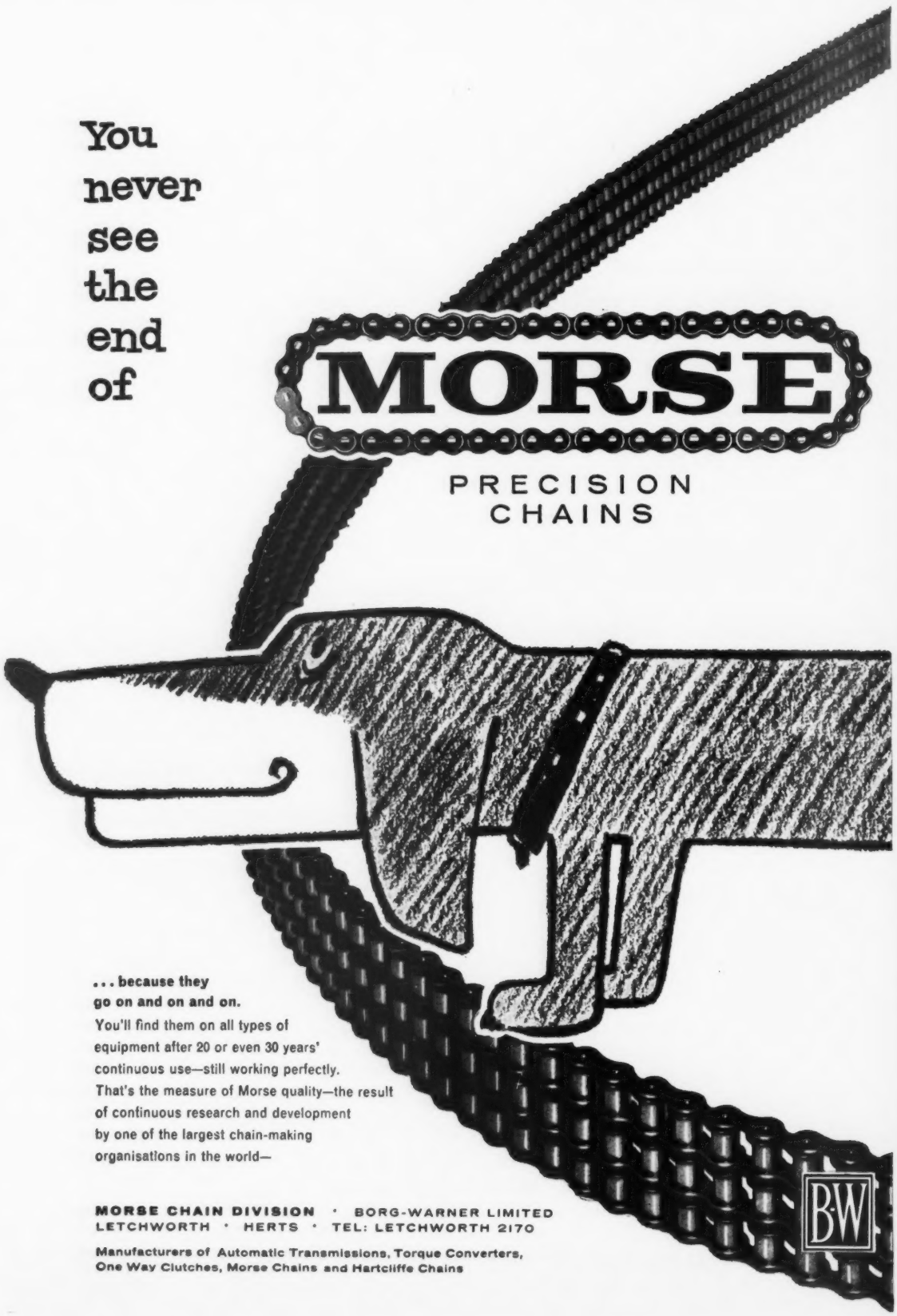

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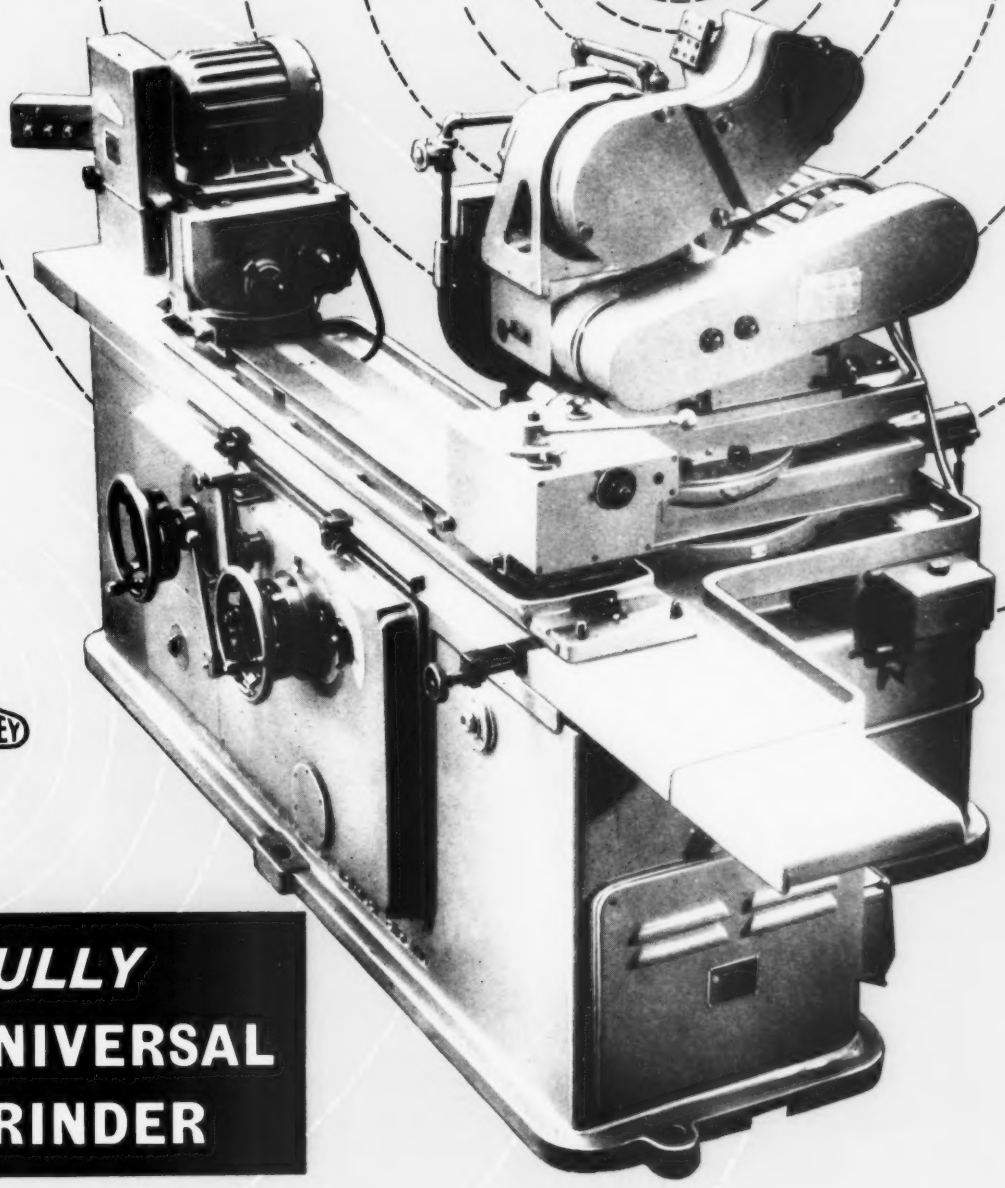

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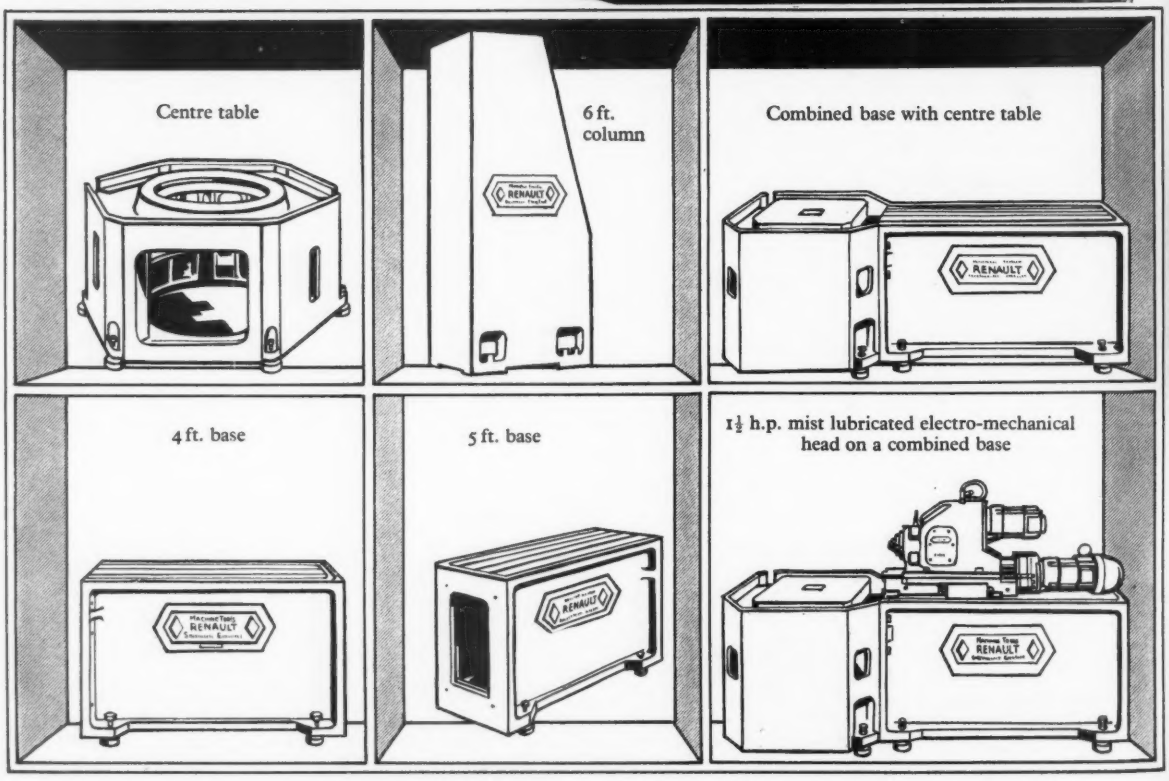
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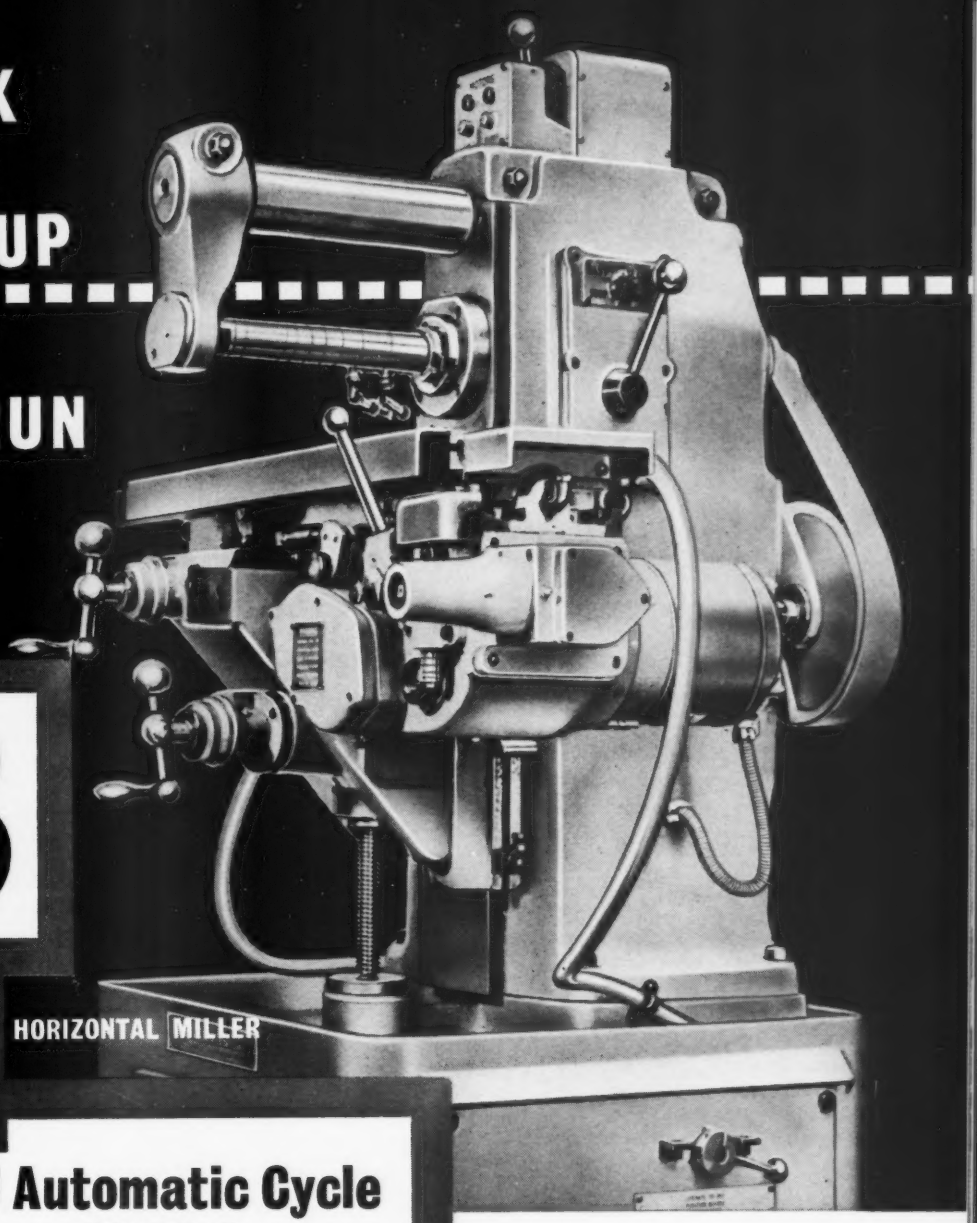

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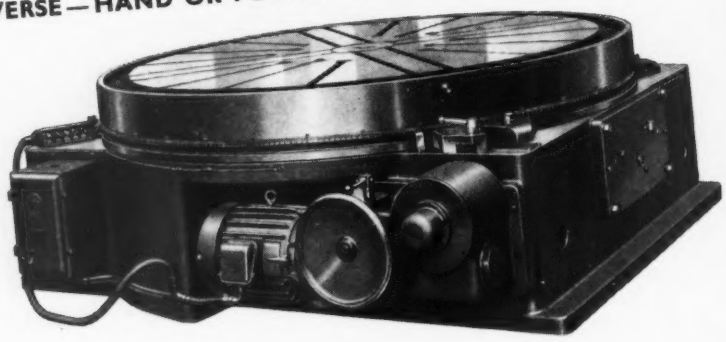

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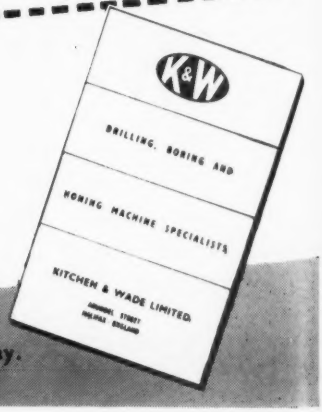

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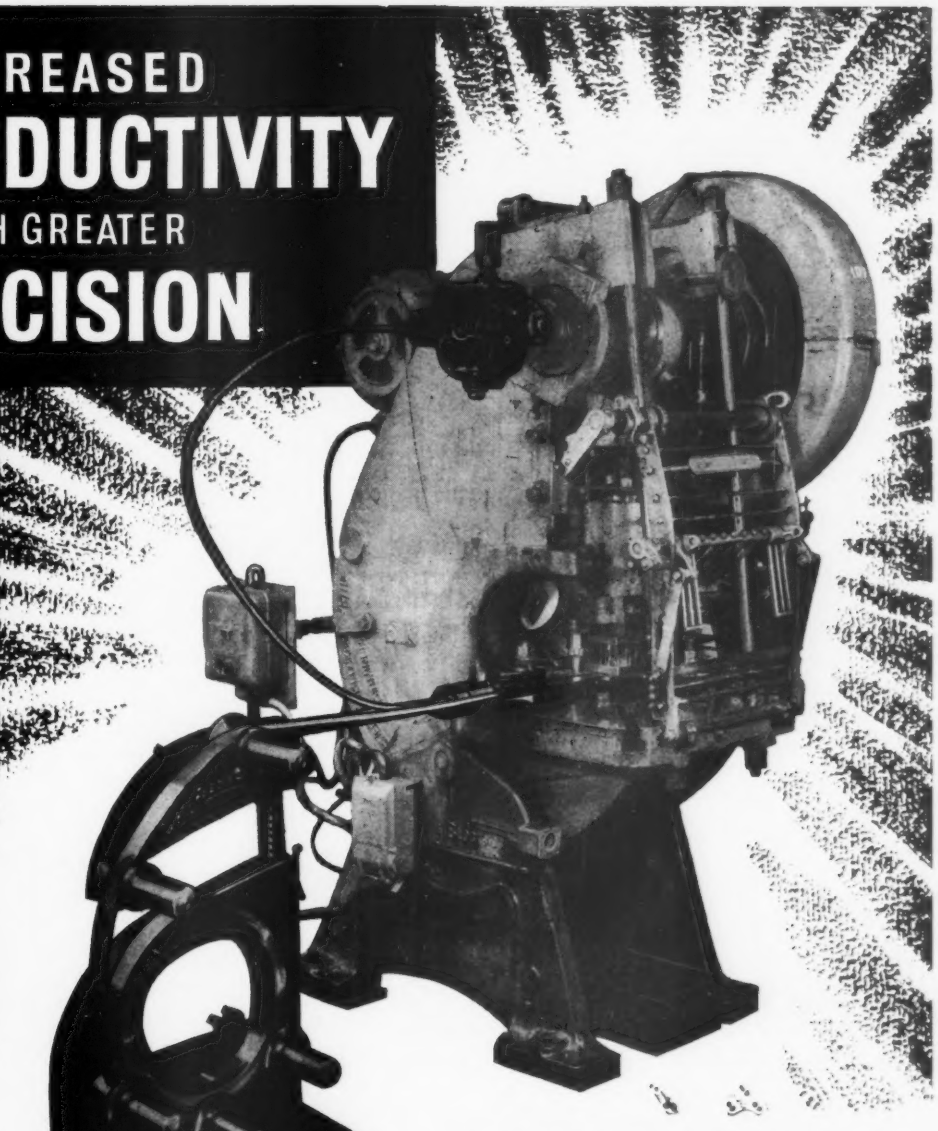

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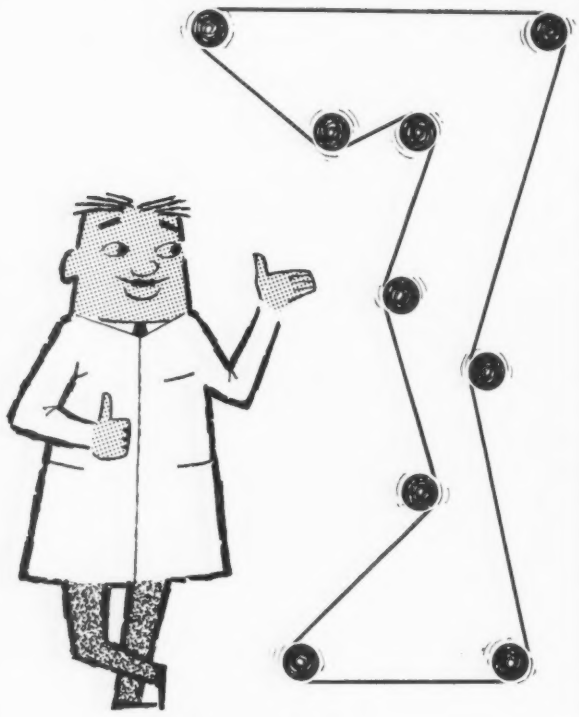

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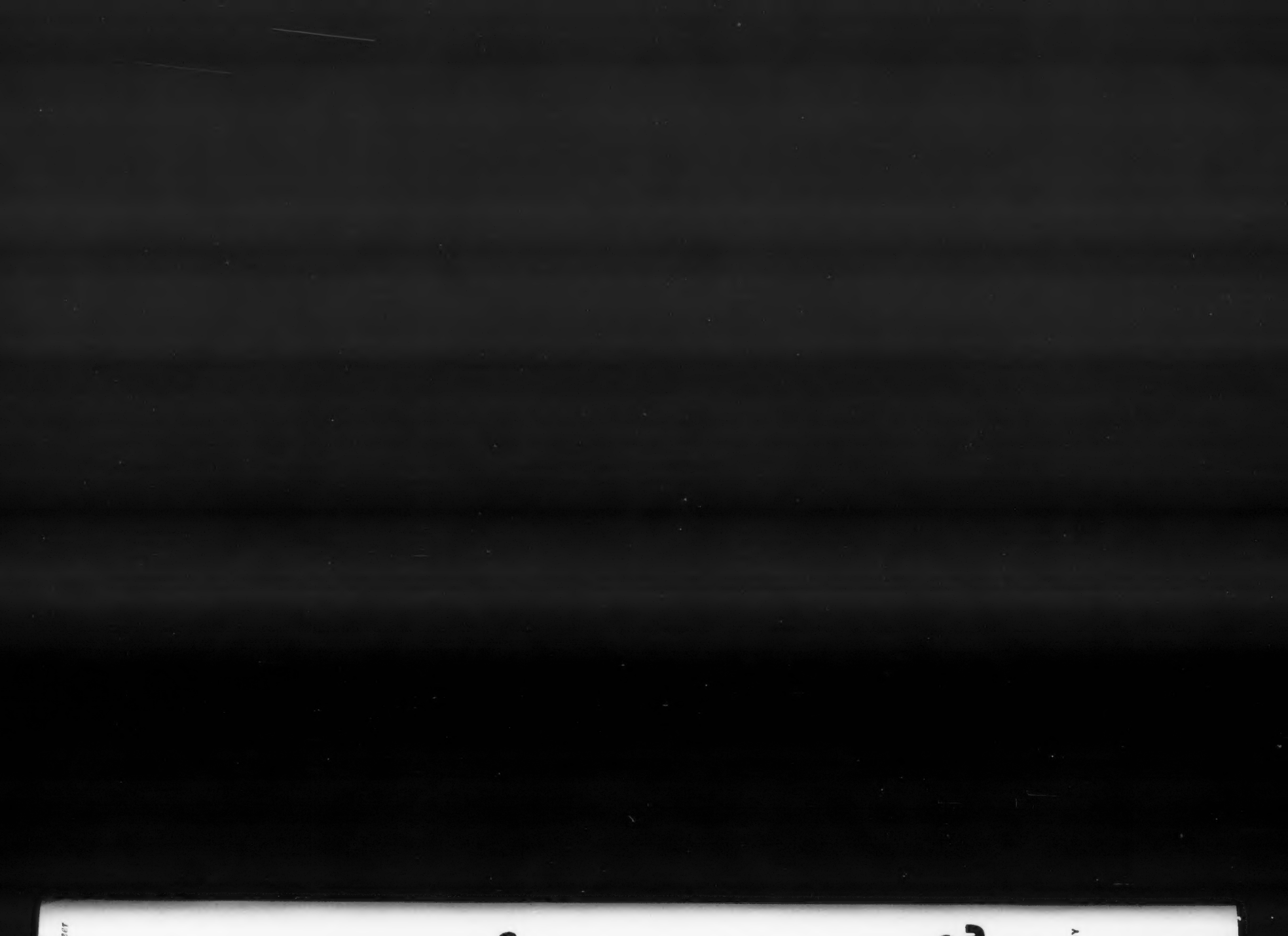

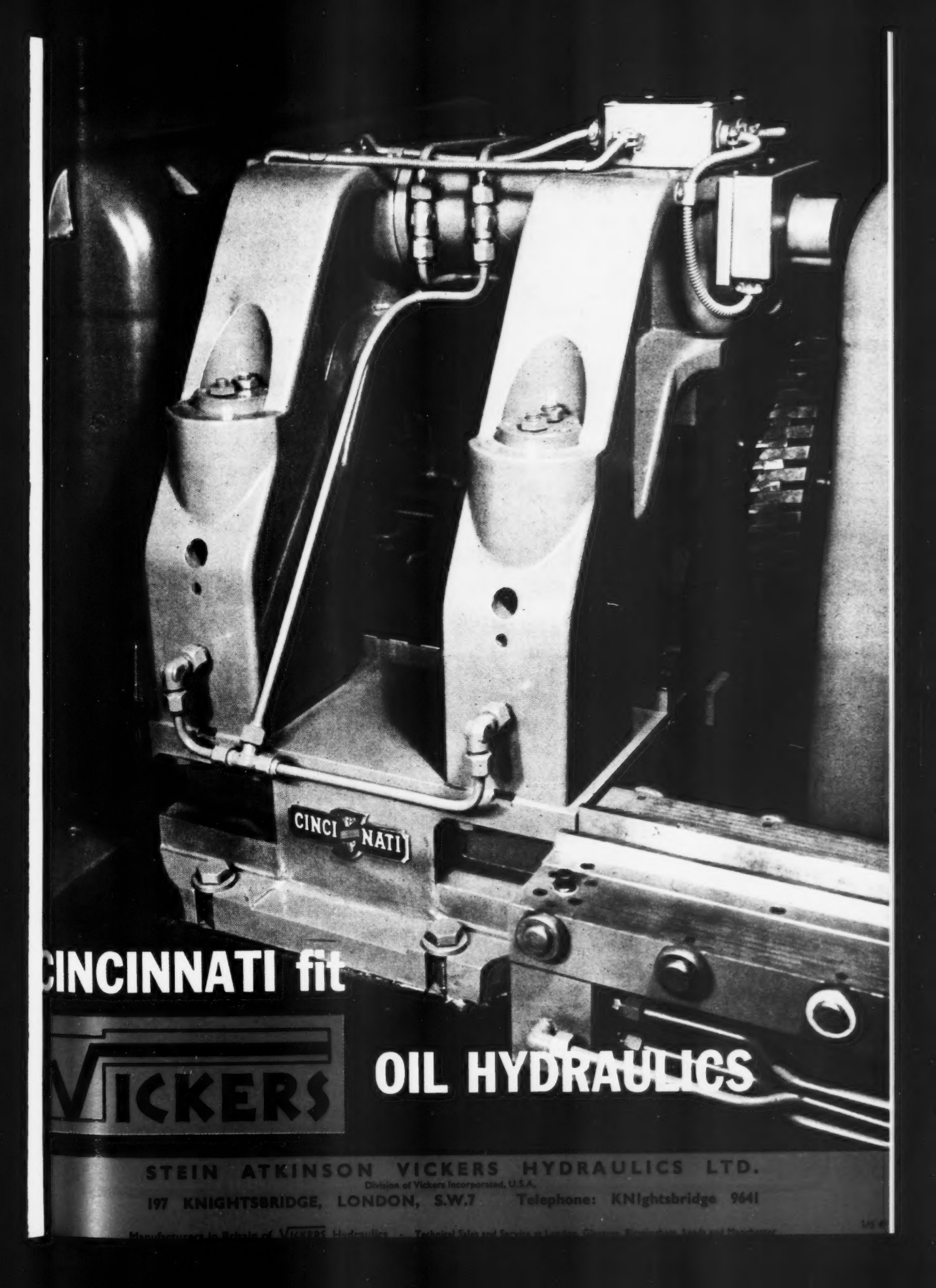

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VICKERS

OIL HYDRAULICS

STEIN ATKINSON VICKERS HYDRAULICS LTD.

Division of Vickers Incorporated, U.S.A.

197 KNIGHTSBRIDGE, LONDON, S.W.7 Telephone: KNightsbridge 9641

Manufacturers in Britain of VICKERS Hydraulics ... Technical Sales and Service at London, Glasgow, Birmingham, Leeds and Manchester

MATRIX QUALITY

British Built

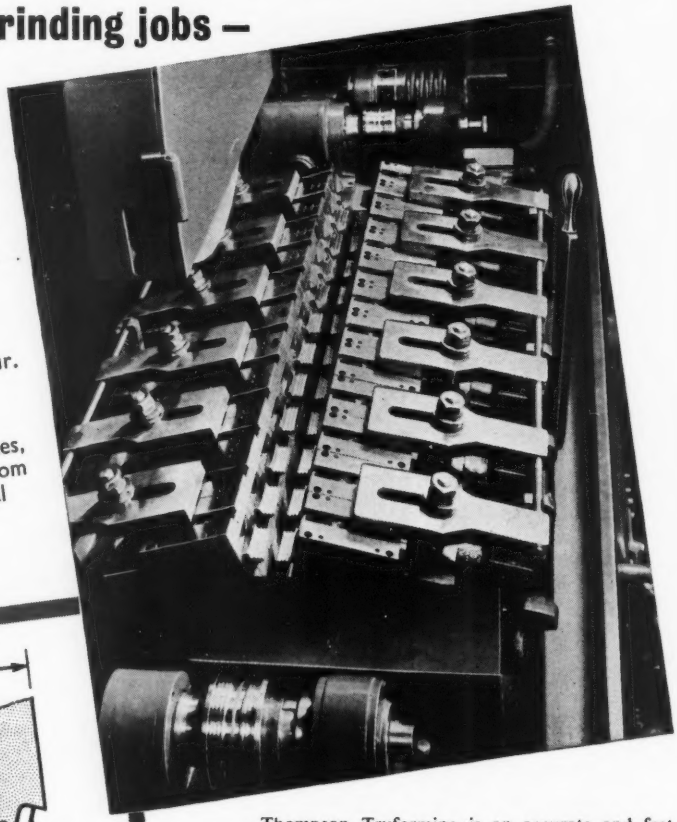
THOMPSON

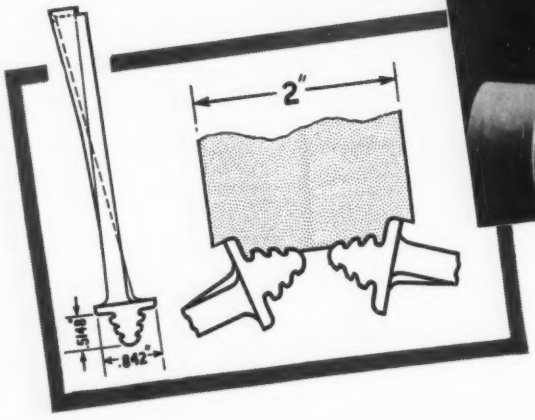
TRUFORMING GRINDERS

Manufactured by COVENTRY GAUGE & TOOL COMPANY LTD.

save time on form grinding jobs —

PART NAME: Jet Engine Blade.
METHOD OF HOLDING: 24 Place Fixture.
METHOD OF GRINDING: "Truforming" Two Rows (12 per row) from Solid — ·100 in. Stock Removal per Side.
MACHINE SIZE: Type "C" 12 x 16 x 44 Truform Grinder.
PRODUCTION: 33 pieces per hour.
NUMBER OF PIECES PER WHEEL DRESSING: 96.
CRUSHER ROLL LIFE: 864 pieces, before regrinding Work Roll from Reference Roll to restore initial accuracy.





Thompson Truforming is an accurate and fast method of producing identical parts by transferring the shape or form of a preformed crushing roll first to the grinding wheel and then to the work. The crushing process produces a very free cutting wheel which gives an exceptionally high rate of stock removal.

It has many time-saving and product-improving applications, including the elimination of difficulties encountered in maintaining tolerances as grinding is carried out after hardening.

Sole Agents in U.K.

ROCKWELL
MACHINE TOOL CO. LTD.

For further particulars write or telephone TODAY

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THOMPSON 6

That's very bright of you, Mr. Smart

Mr. Smart's come a long way from the snap-shot album he used to inflict on his friends. Now he projects his latest holiday shots in colour—and *everyone* enjoys them. Life is very much brighter for Mr. Smart and millions of others, thanks in no small measure to the bright ideas of the manufacturers who serve them.

One of their brightest ideas was to use pressure die castings, now an essential part of so much of your photographic equipment.

And an essential part of many other things too. Wolverhampton pressure die castings offer manufacturers high quality components at remarkably low cost in a variety of pleasing finishes.

And the massive scale of production they can achieve helps everyone to enjoy a higher standard of living.

Wolverhampton pressure die castings in zinc and aluminium point to progress in a big way.

Your enquiries would be welcomed.

THE WOLVERHAMPTON DIE CASTING COMPANY LIMITED

GRAISELEY HILL, WOLVERHAMPTON. TELEPHONE: WOLVERHAMPTON 23831

The pressing assembly as produced by HOOVER Ltd for their KEYMATIC Washing Machine in their Merthyr Tydfil Press Shop illustrated on the opposite page.

... THE APPLIANCE FIELD

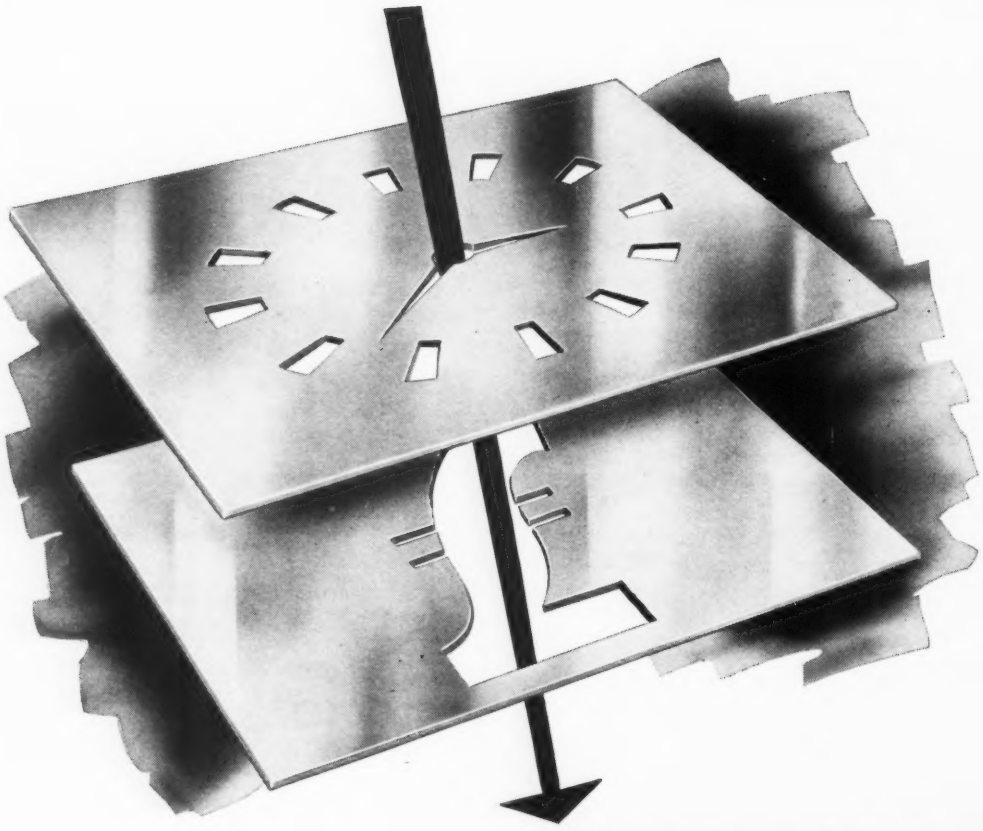
The preference of so many of the busiest manufacturers in the appliance industries for Wilkins & Mitchell Power Presses, especially in their most recent installations, is based on their need for higher productivity. Throughout the world, users have learned to rely on the design, dependability and built-in reserves of Wilkins & Mitchell Presses . . the complete press shop . . or the single press. Why not consult us on your press requirements ?

WILKINS & MITCHELL PRESSES (150 to 350 tons—36" to 108" between uprights) at work on HOOVERS latest washers.

WILKINS & MITCHELL

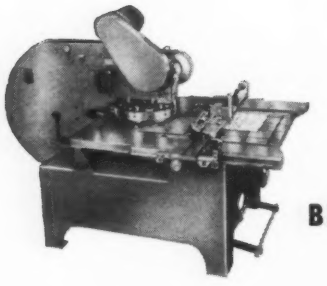
The Presses that cut costs

WILKINS & MITCHELL LTD . DARLASTON . S. STAFFS . ENGLAND



WIEDEMANN

pierces the Time and Cost Barrier....



Wiedemann cuts the cost of short and medium run piercing by as much as 85% and does the job much better and much faster. No more marking out— No more setting up, drilling, flycutting, chiselling out or finishing to size and *no more costly tooling.* Modifications or complete changes of layout made quickly, easily, cheaply.

Write for Wiedemann Brochure No. /176 and study the 'hole' time and cost question—and send sketches of some of your jobs and ask for time studies.

BRITISH WIEDEMANN TURRET PUNCH PRESSES

RA. 41P with pantograph table and stylus for rapid hole location. Throat depth 28" with 16, 18 or 20 turret stations. 30,000 lbs. capacity. Other models—hand and power operated—15,000 to 160,000 lbs. punching pressure.

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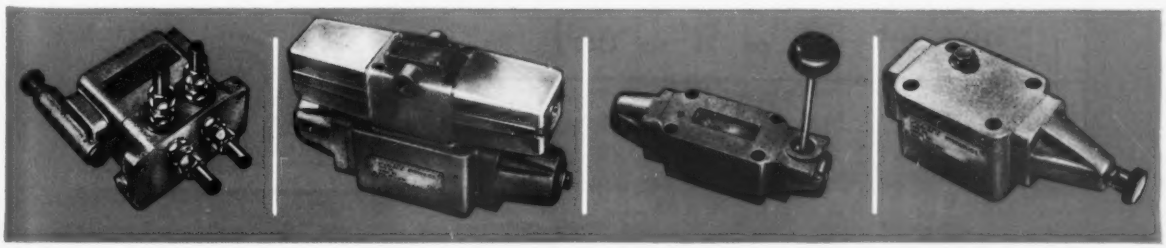
PRATT

HYDRAULIC

variable flow-control valve

CONTROL VALVES

Variable Flow Control Valves, 3 cu. inches per minute to 10 gallons per minute.
The Control Valves are part of a complete range of Hydraulic Control Equipment to meet the needs of every industry.
Pratt Valves are gasket mounted. Ratings up to 10 gallons per minute and 2,000 P.S.I.
Qualified Pratt Engineers are always ready to advise on equipment and circuits.



PRATT PRECISION HYDRAULICS LTD.
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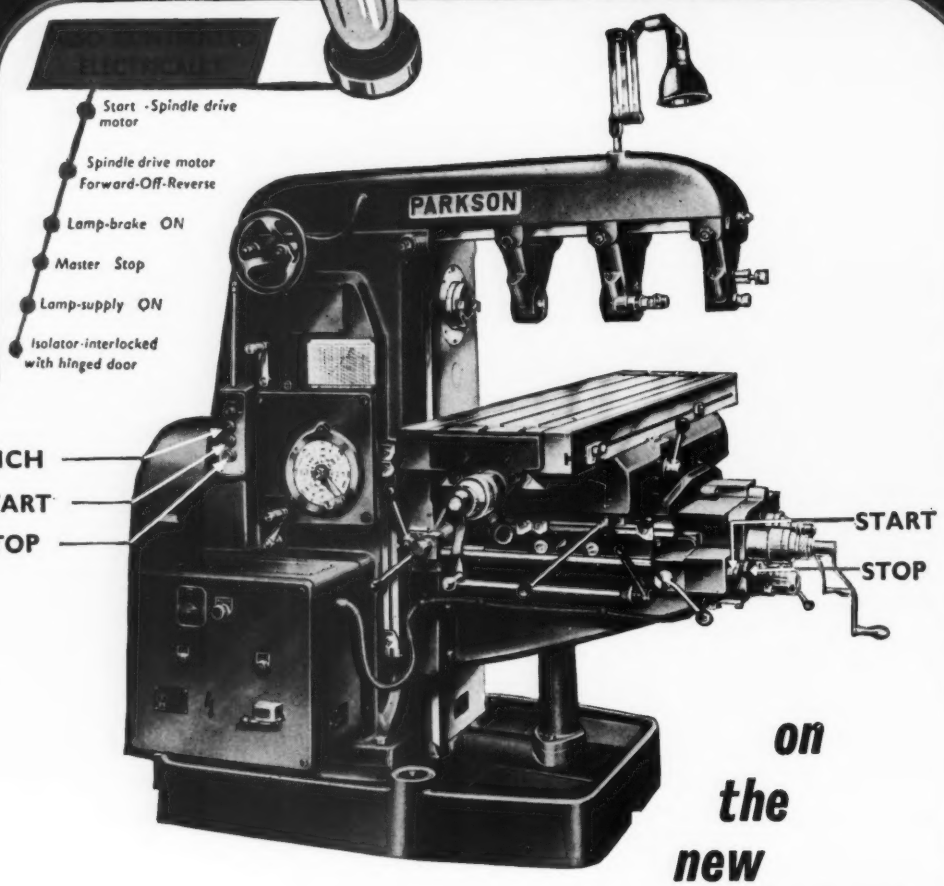
A Subsidiary of F. PRATT & COMPANY LIMITED Famous for Workholding for 100 Years

EASIER STILL TO OPERATE WITH

Push-Button Controls



PLAIN MILLER ILLUSTRATED

on the new **3N PARKSON MILLERS**

28 Spindle Speeds in range as selected. — 17 to 1000 or 23 to 1330 or 25 to 1500 } r p m

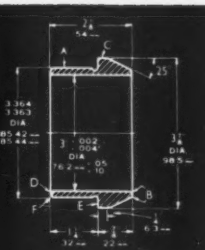
TABLE

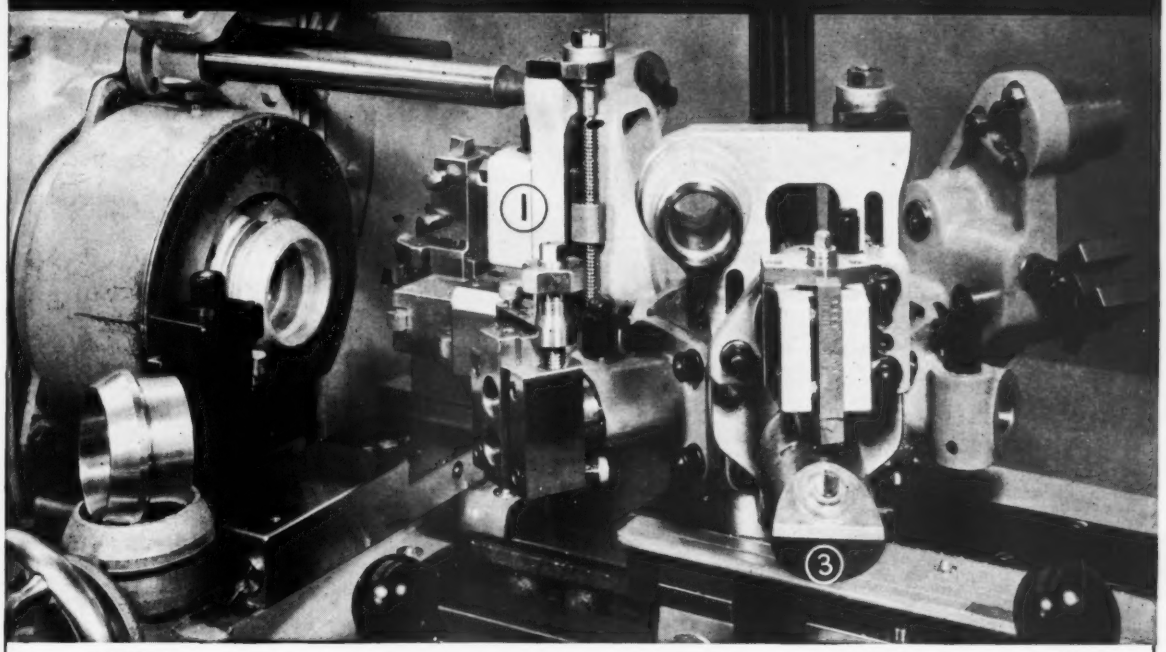
	Size		Movements	
	English (inches)	Metric (mm.)	English (inches)	Metric (mm.)
Plain	70 x 16½	1780 x 420	40 x 12 x 18	1015 x 305 x 455
Universal	60 x 14	1525 x 355	36 x 12 x 18	915 x 305 x 455

J · PARKINSON & SON (SHIPLEY) LIMITED
SHIPLEY · YORKSHIRE · ENGLAND
TELEPHONE SHIPLEY 53231

P389-1B

Ward SPECIAL TOOLING LAYOUT No. 12





BUSH
Machined all over.

Floor to Floor Time :
1 mins. 20 secs.

2DS CAPSTAN LATHE

Code Word : **Twods**

Equipped with 7½″—3-Jaw Air Chuck.

BRASS STAMPING
Tungsten Carbide Cutting Tools.

DESCRIPTION OF OPERATION	Tool position		Spindle Speed R.P.M.	Max. Cutting Speed		Feed	
	Hex. Turret	Cross-slide		Feet per min.	Metres per min.	Cuts per inch	m/m. per rev.
1. Chuck on "A"	—	—	—	—	—	—	—
2. Rough bore 3″ dia., knee turn 3⅞″ dia., face end and double chamfer "B"	1	—	1360	1430	435	214	·119
Turn 25° taper	—	Rear	—	—	—	—	—
3. Reverse component in chuck and grip on "C"	—	—	—	—	—	—	—
4. Face "E", form undercut, face end and chamfer "F"	—	Front	1360	1380	420	Hand	Hand
5. Finish microbore 3″ dia., knee turn 3·364″ dia. and radius "D"	3	—	1360	1250	380	214	·119
6. Remove	—	—	—	—	—	—	—

'PRELECTOR' Combination Turret Lathes with Preselective speed-changing.

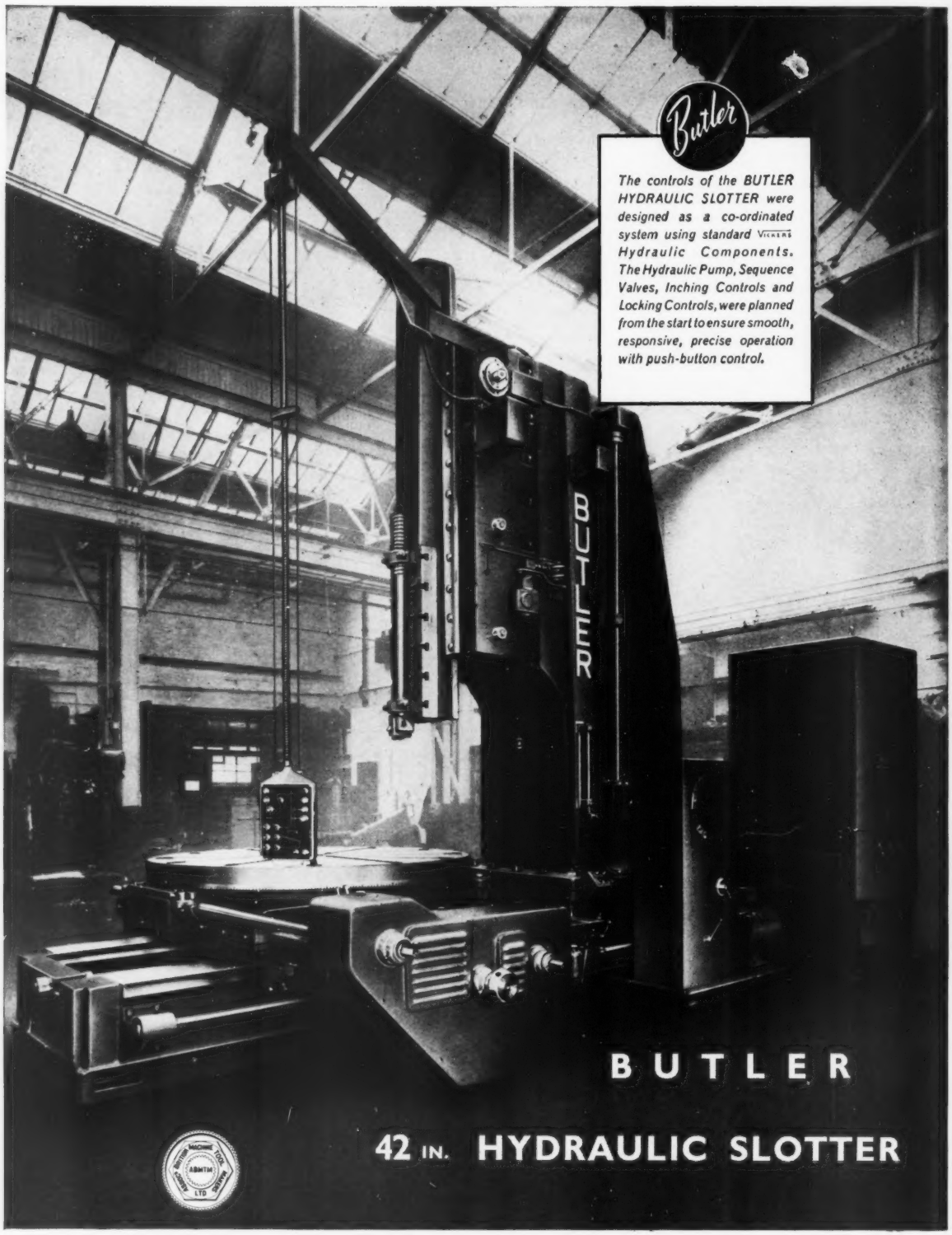
TURRET LATHES with capacities up to 35 in. swing over bed

1½ in. to 2½ in. 'D-S' DOUBLE-SLIDE Capstan Lathes for heavier accurate work.

Stock Tools, Toolholders, Chucks and Accessories for Capstan and Turret Lathes.

H. W. WARD & CO LTD
SELLY OAK, BIRMINGHAM 29
Phone : Selly Oak 1131

ASSOC. BRITISH MACHINE TOOL MAKERS ABMTM LTD


Butler
The controls of the BUTLER HYDRAULIC SLOTTER were designed as a co-ordinated system using standard VICKERS Hydraulic Components. The Hydraulic Pump, Sequence Valves, Inching Controls and Locking Controls, were planned from the start to ensure smooth, responsive, precise operation with push-button control.
BUTLER
BUTLER
42 IN. HYDRAULIC SLOTTER

The BUTLER MACHINE TOOL Co. LTD.

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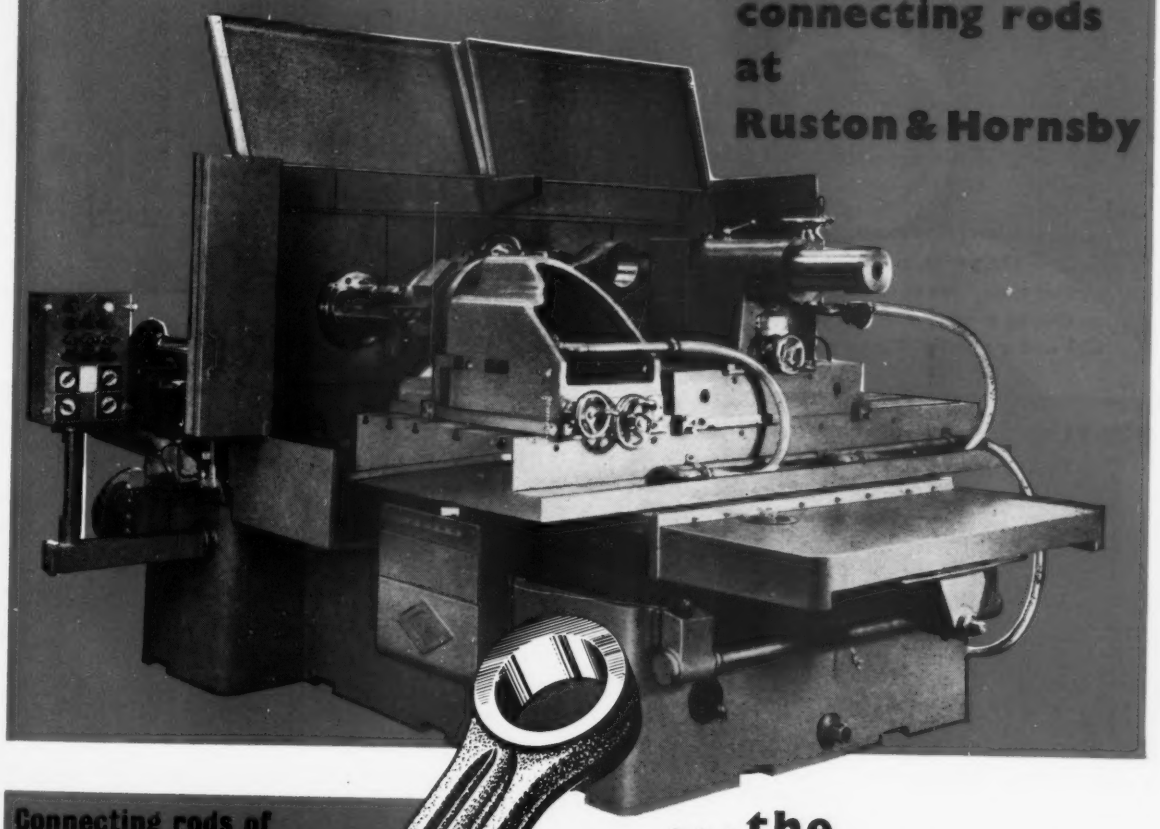
ENGLAND
TELEPHONE 61641

FOR PLANING SHAPING AND SLOTTING MACHINES

B330-1B

Fine boring...

connecting rods at Ruston & Hornsby



Connecting rods of the Ruston 'AT range' diesels with powers from 700 to 1800 b.h.p. Weight 370 lb.

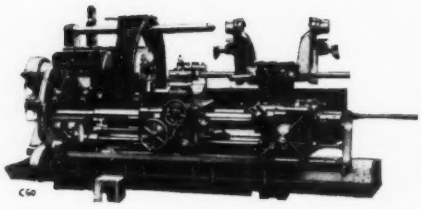
...the PRECIMAX way

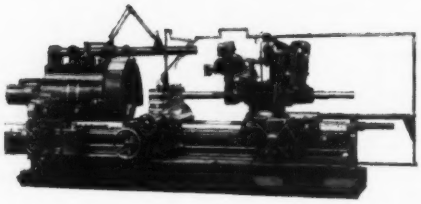
A Precimax FBI/9 special is chosen to ensure roundness, parallelism and consistent centre distance of large and small bores of connecting rods. These components, of 45 ton tensile steel, are rough and finished bored to 0.001" with stock removal of 0.062" from each diameter, surface finished to 32 micro inches in 13 minutes. This machine with electro-hydraulic control, fine bores several sizes of rods and provides for machining of special articulated types.

LANDIS LUND LIMITED

CROSSHILLS—KEIGHLEY—YORKSHIRE

FOR HEAVY TURRET LATHE WORK

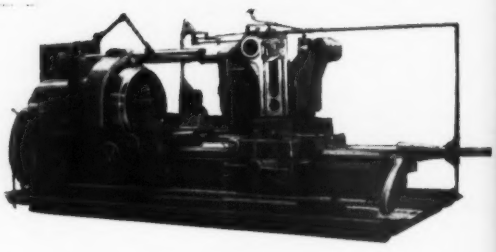




The Herbert range of powerful and rigid lathes for heavy cuts at coarse feeds on all work up to 36″ swing; unsupported light work up to 45″ swing.

Have advantages common to Herbert Capstan Lathes—the power, speeds and feeds to use carbide tools, ease of setting-up for economical machining of small batches, fast cutting times, high and consistent accuracy and excellent finish

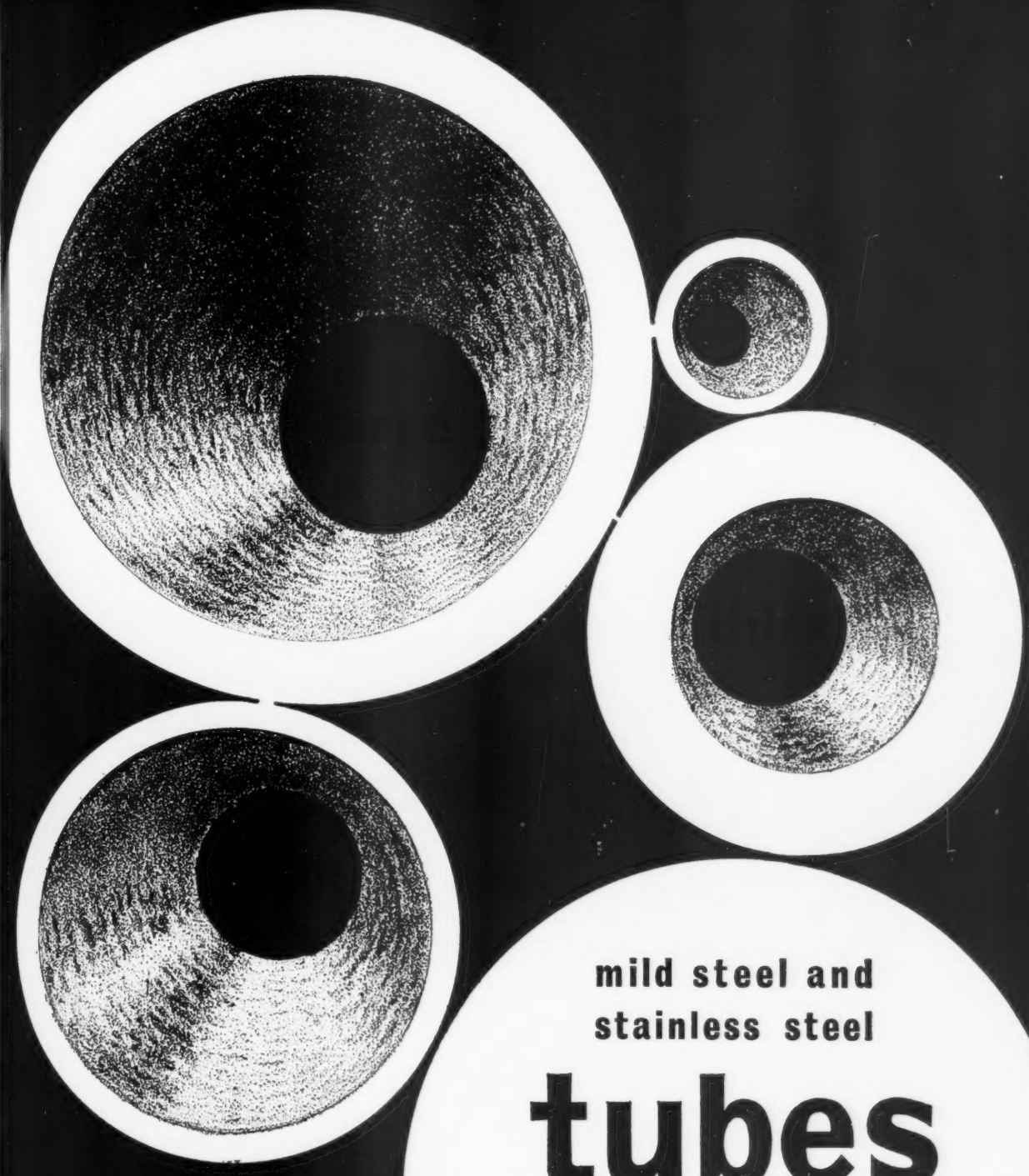
On this Herbert No. 14/36 Combination Turret Lathe at the Caterpillar Tractor Co. Ltd., Newcastle, a 50 h.p. motor and Ardoloy tools permit heavy metal removal when machining a 34 in. diameter rim collar from a steel forging.



Herbert Turret Lathes are available in 7 sizes; cross-sliding turret and combination turret types.

ALFRED HERBERT LTD., COVENTRY

AD518



mild steel and stainless steel

tubes

from stock—in randoms or cut to length. Do you have our stocklist of standard and non-standard tube?

Markland Scowcroft LTD

Bromley Cross Nr. Bolton *Telephone: EAGley 600*

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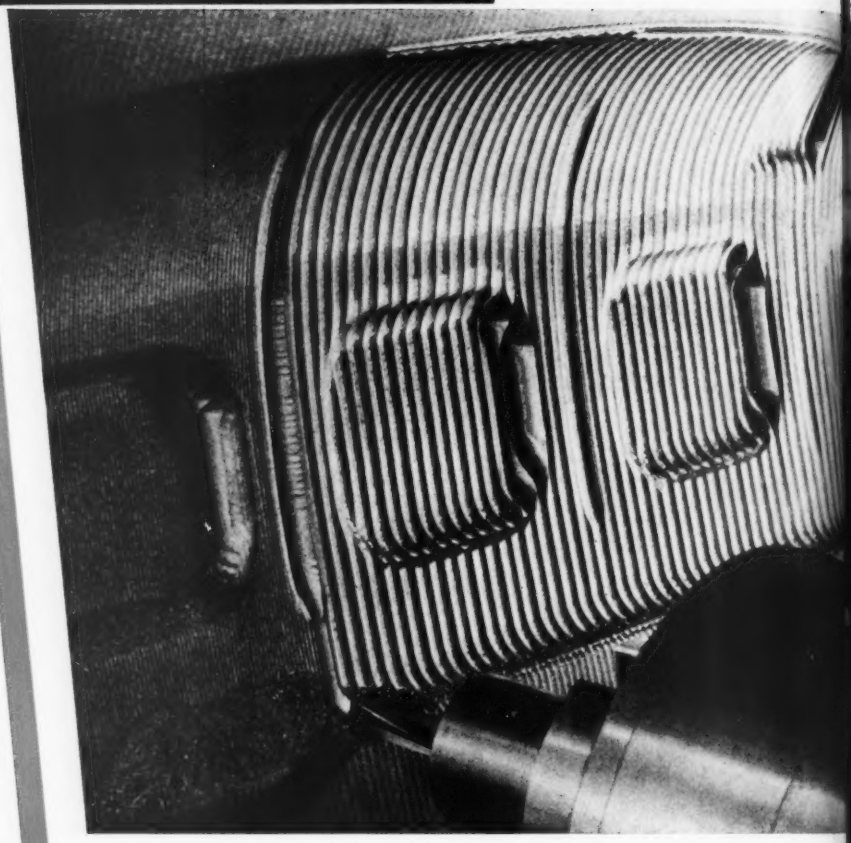

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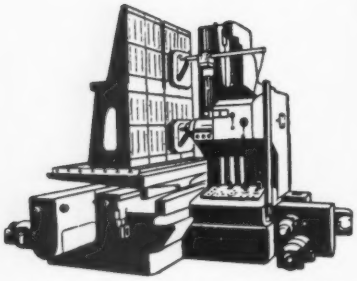
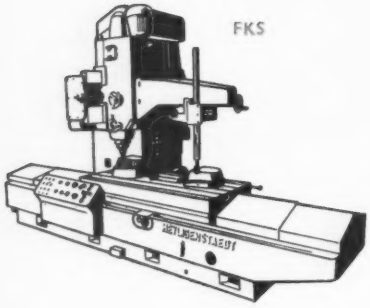
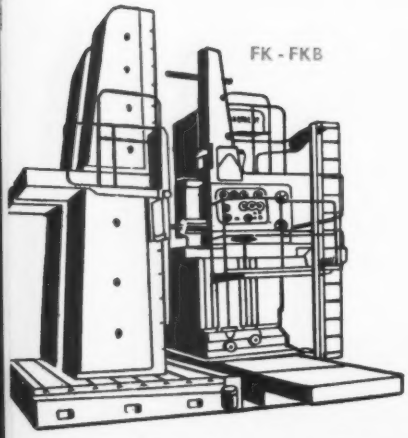


FKS



FK - FKB



A Drawing Die is automatically copied!

The highly sensitive tracer of the Copy-Milling Machine is in contact wi the contour of the wood or plaster master piece and reliably transfers t shape to the workpiece. Three basic models of Automatic Copy-Milli Machines are available. Each Model can be supplied in several versio differing in spindle size, milling range, and dimensions.

Models FKT :
Table machines for horizontal milling; compound table.

Models FKS :
Table machines with vertical milling spindle; longitudinal-movem table.

Models FK :
Floor type machines with moving column; horizontal milling spind Model FKB is additionally equipped with a boring spindle.

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A Battery of four Réel Cranes supplied and erected for a continental customer

BRITISH INDUSTRIAL

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. . . the complete grinding
plant was built by
Edgar Allen's

I didn't know
they did this
kind of work . . .

. . . Well—I thought they
only made tool steels

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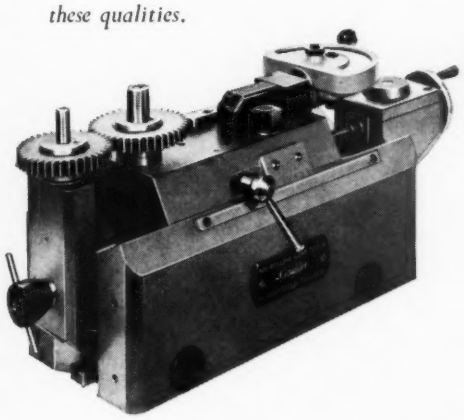
EDGAR ALLEN & CO LIMITED
STEELMAKERS AND ENGINEERS · SHEFFIELD 9

P5

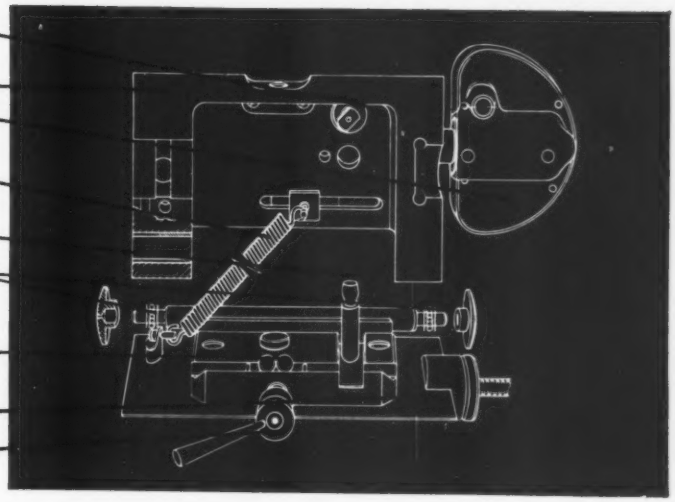
Goulder GEAR MEASURING EQUIPMENT

This series of advertisements is intended to show how attention to detail design backed by careful and precise manufacture has made Goulder gear measuring equipment first choice of buyers who appreciate these qualities.



ROLLING TESTER SADDLE ASSEMBLY

used on Goulder No. 1 Rolling Tester to measure variations in centre distance as two gears are rolled together under spring pressure and hence composite gear errors. Special layout of saddles allowing 1, vertical adjustment for gear under test 2, extra sensitivity 3, reduced bed length.


CAM ACTION CENTRALISING LOCK TO PROVIDE DATUM
FLOATING SADDLE IN NITRALLOY STEEL
MICRO-INDICATOR AS ALTERNATIVE TO ELECTRONIC RECORDER
SPRING TO PROVIDE ADJUSTABLE MEASURING PRESSURE
STYLUS ABUTMENT PEG
REAR BEARINGS CONSISTING OF TWO RINGS OF BALLS CARRIED ON A HARD STEEL SHAFT IN A HARD STEEL BUSH
FRONT BEARINGS CONSISTING OF TWO BALLS CARRIED IN HARD VEE AND FLAT BEARINGS
SLIDING SADDLE IN HARDENED NITRALLOY STEEL
CAM ACTION LOCK FOR CENTRE DISTANCE SETTING

Goulder *THE NAME FOR ALL GEAR TESTING*

J. Goulder & Sons Ltd., KIRKHEATON, HUDDERSFIELD. *Tel: Huddersfield 5252-3*

19.17

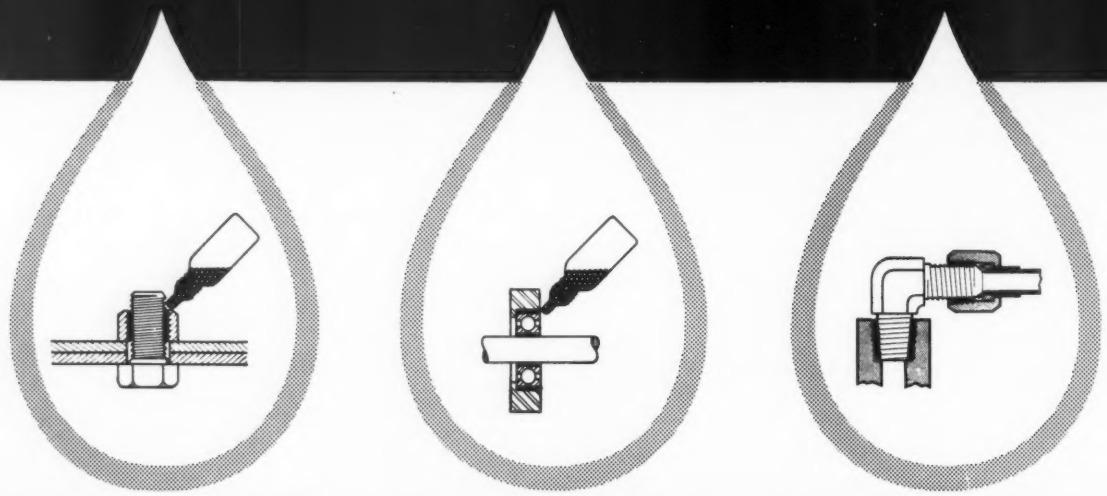
LOCTITE SEALANT

TRADE MARK

The Drop that Holds

This remarkable liquid plastic now widely used in every industry penetrates between closely fitting metal parts and hardens automatically inside the joint to give a vibration-proof lock and leak-proof seal. LOCTITE treated parts NEVER WORK LOOSE, yet can be removed with ordinary tools.

Min. of Aviation and A.R.B. approved



LOCTITE Sealant LOCKS THREADS

Loctite Sealant will lock nuts, set screws, studs, adjustment screws, etc. It makes them self-locking and dispenses with lock nuts, lock washers and other locking devices. Threads can be pre-treated in quantities, as Loctite Sealant does not harden while exposed to air.

Loctite Sealant locks bolts on giant earthmoving equipment permanently against vibration, yet bolts can be removed with ordinary tools!

LOCTITE Sealant RETAINS BEARINGS

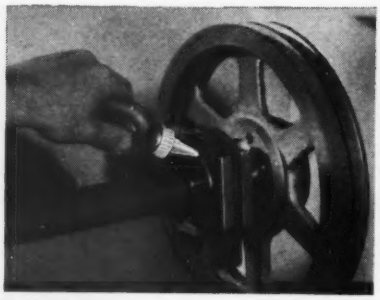
Loctite Sealant restores the fit to worn housings and shafts. Holds bearings, gears, pulleys, sleeves, oil seals without a press fit. Eliminates re-boring, sleeving, shims and weld metal build-up. Loctite Sealant automatically fills clearance, prevents slippage.

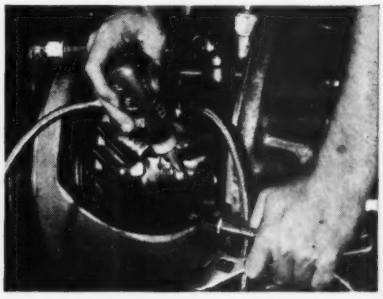
Loctite Sealant is used on assembly of bearing in lieu of press fit.

LOCTITE Sealant SEALS JOINTS

Loctite Sealant seals against high pressure liquids and gases, completely filling the joint with tough plastic, resistant to heat, cold, water, oils, fuels and most chemicals. Replaces solder, requires no heat or fluxes.

Loctite Sealant seals hydraulic and fuel lines permanently leak-proof. Joints cannot work loose yet can be dismantled for servicing.





We will be pleased to send you the new illustrated LOCTITE Sealan. Brochure giving full details and specifications. Write to Mr J. Jenkins

LOCTITE TRADE MARK SEALANT

THE LIQUID LOCK FOR METAL PARTS

"LOCTITE" is the trade mark of the American Sealants Company U.S.A.

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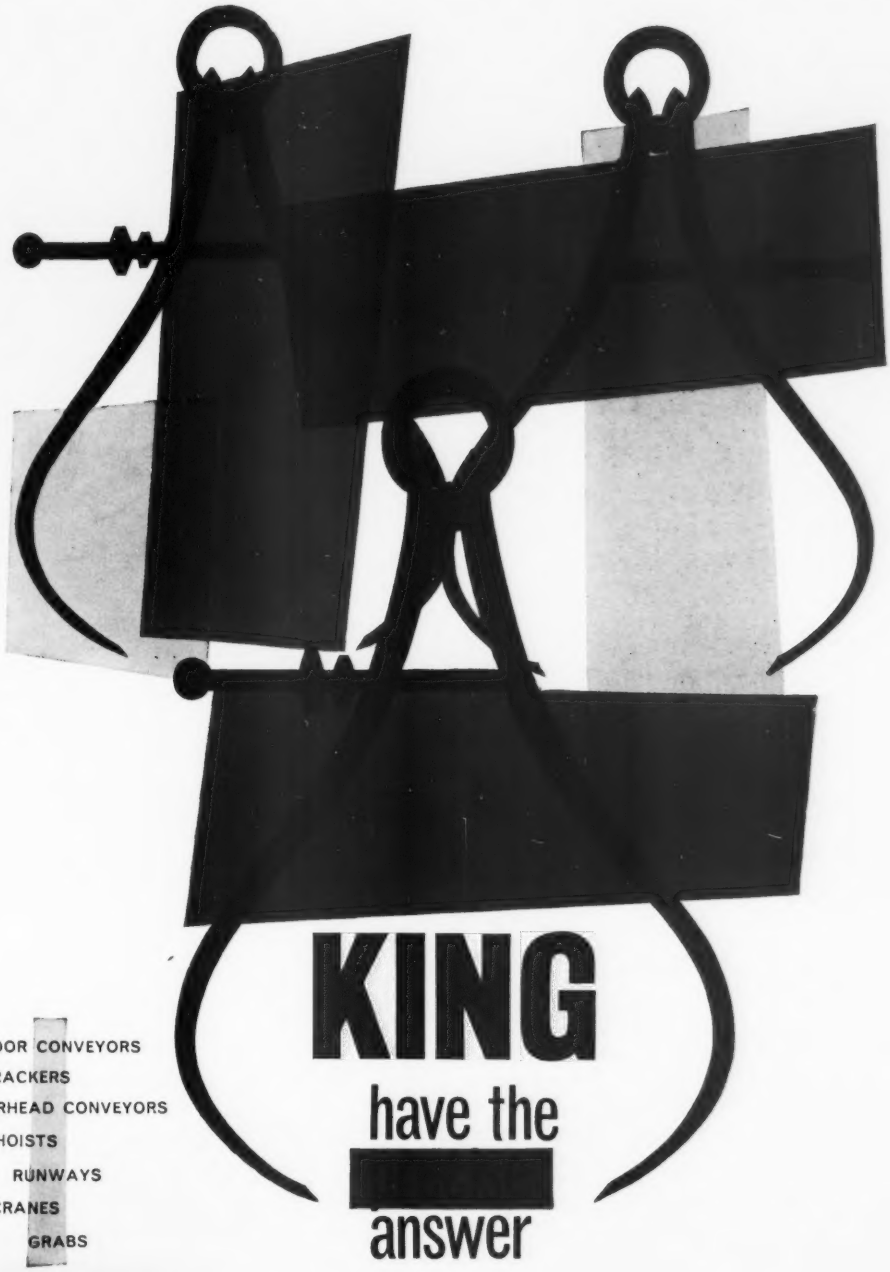
AP 130

for all materials handling problems...



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HOISTS
RUNWAYS
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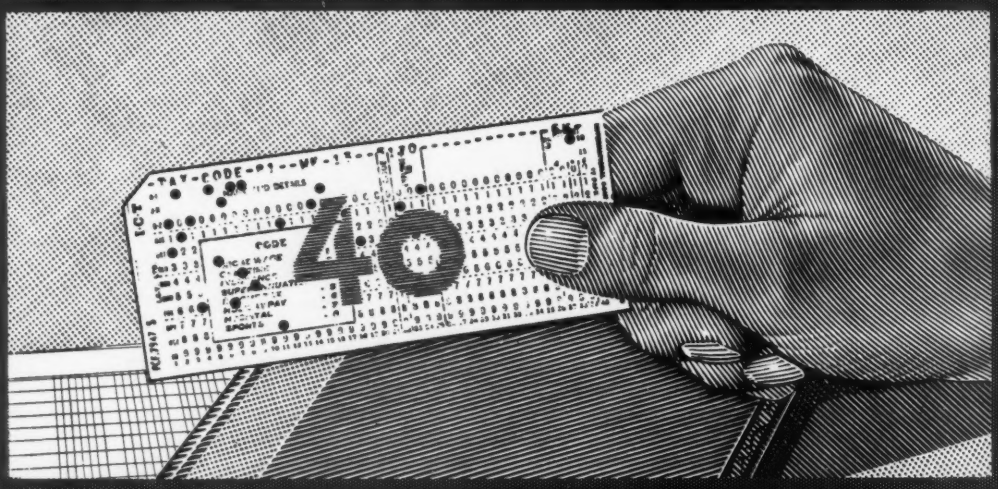

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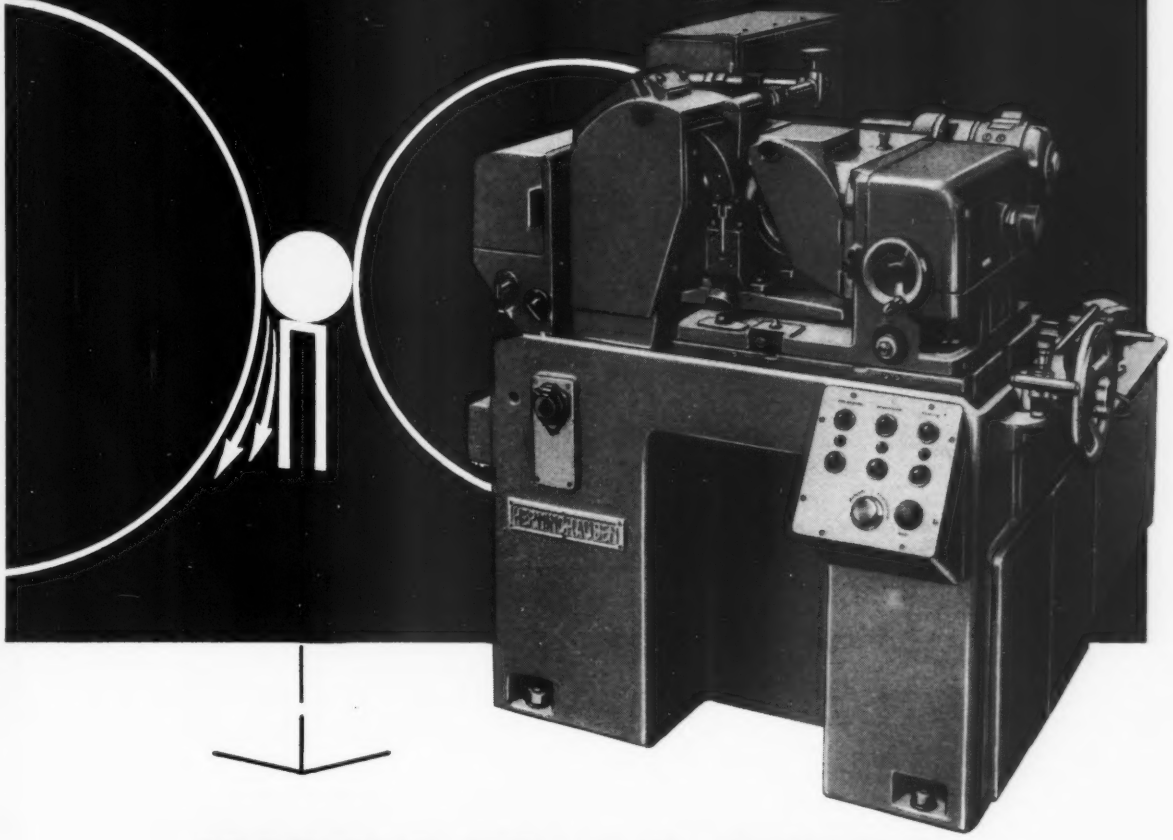

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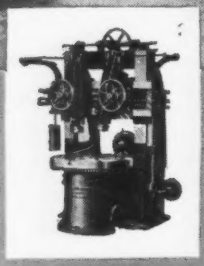

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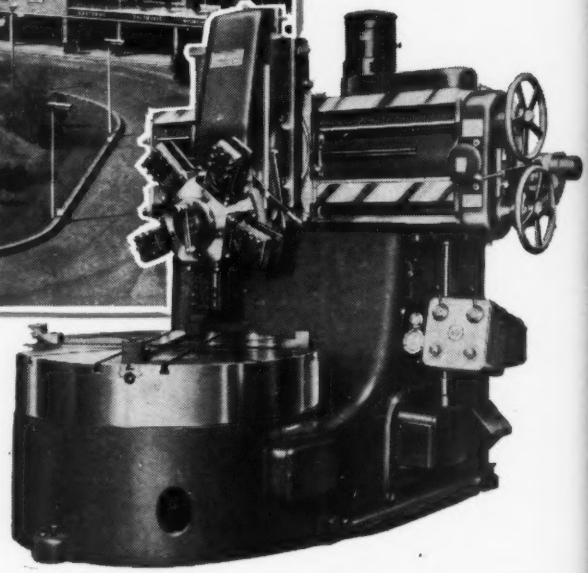

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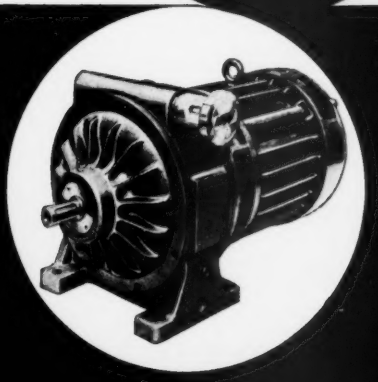

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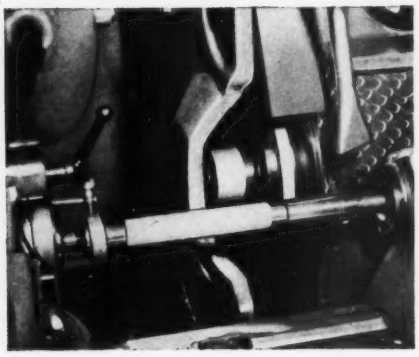

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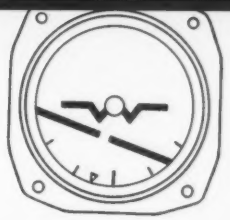

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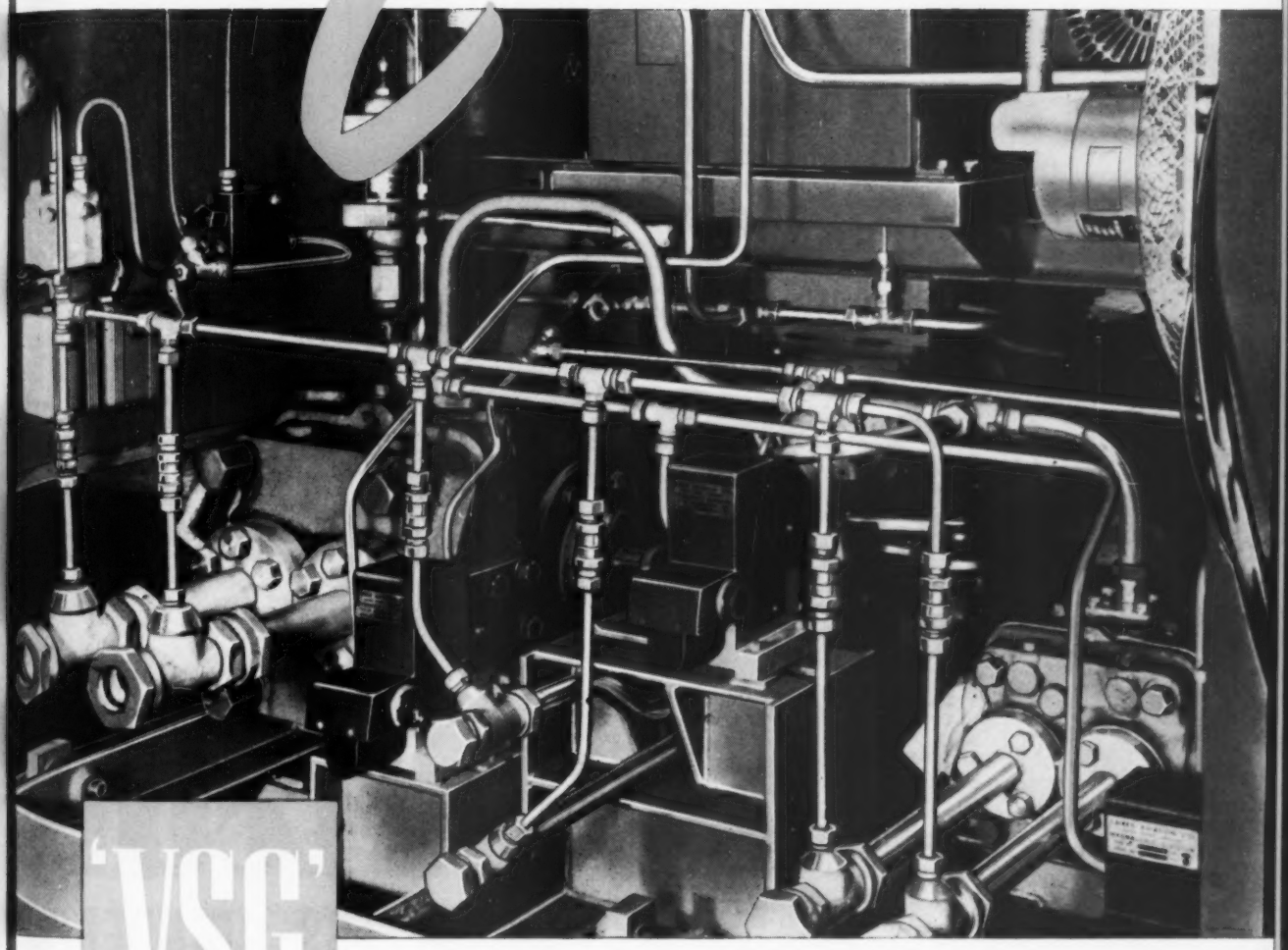

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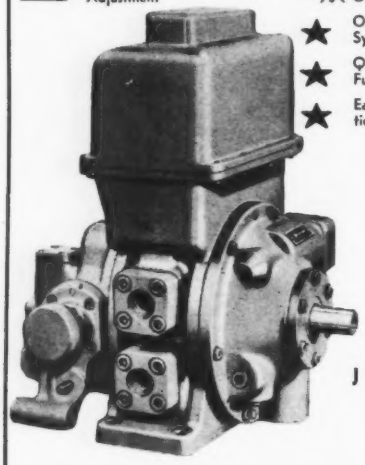

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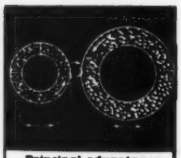

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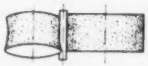

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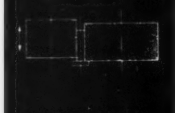

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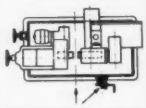

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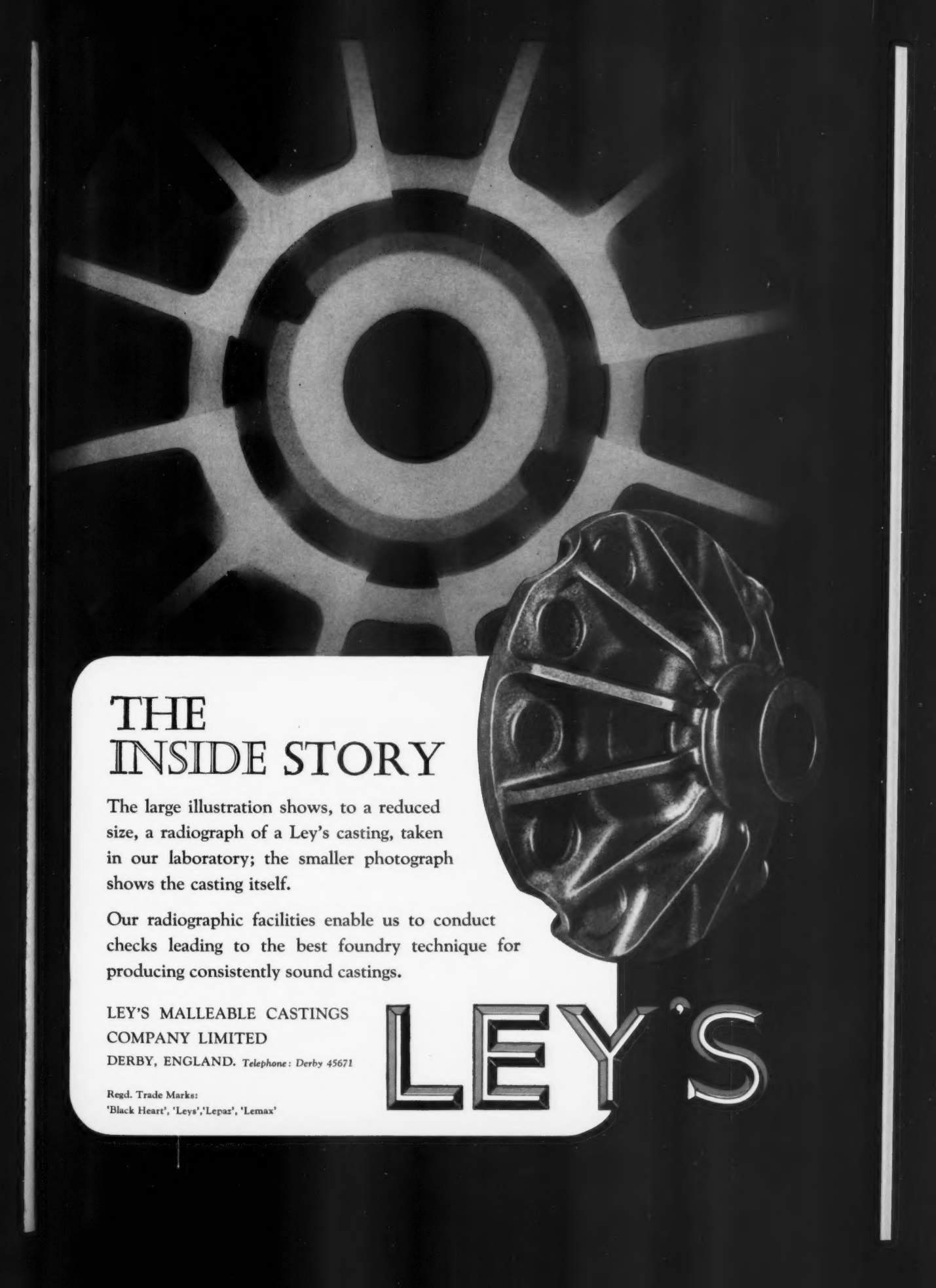

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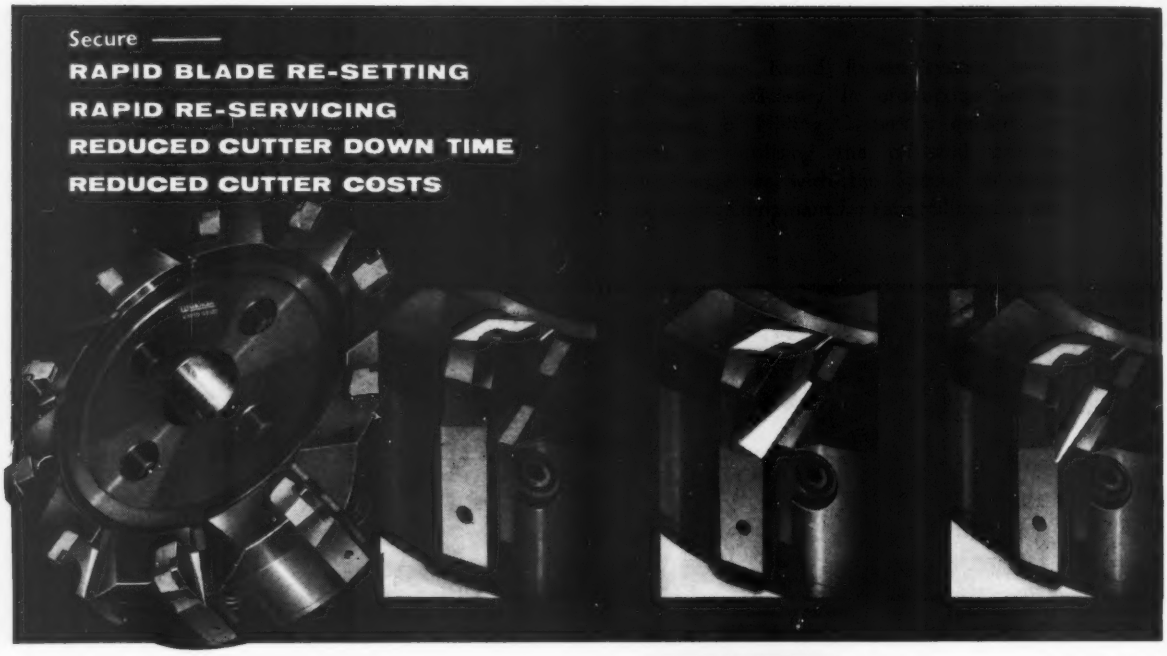

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The Production Engineer

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

VOL. 40 No. 9 SEPTEMBER, 1961

Some Human Aspects of Engineering Progress

by Sir WILLIS JACKSON, F.R.S.

The 1961 Viscount Nuffield Paper,

presented to

The Institution of

Production Engineers

at The University of Bristol,

on 14th June, 1961

MAY I begin by expressing my great appreciation of the honour you have paid me in inviting me to deliver the annual Nuffield Paper to your Institution. I appreciate this the more because I cannot claim to have made any very direct contribution to the achievements and the progress of your branch of engineering activity. My kind of contribution in the fields of research and education lies several stages back from yours, but that it has an important impact on yours is, I think, unquestionable, as I shall try to illustrate later.

I am what, in polite language, is described as an academic type of engineer, and I would have no great confidence in my ability to undertake the duties, and to fulfil the responsibilities, which fall to the members of your Institution. I can say this without embarrassment and with some conviction because I have had a magnificent opportunity, during the past eight years when I have been back in industry, of observing the kind of problems with which—day in, day out—you have to wrestle, and of assessing the technical competence, and the adaptability and resource, which the solution of these problems demand. And I have come to have a profound admiration for the production engineers with whom, at a distance perhaps, I have been privileged to work.

One aspect of my job has been that of trying to stimulate the conception of improved or new forms of electrical equipment and of engineering technique, and of ensuring the availability of basic data required by the design and production engineer. Judgments on the value of this fundamental and applied research must not be based on short-term considerations—in

terms of immediately recognisable benefits to the productive processes of the organisation. Its purpose is to open up new channels of production and to assist in stimulating the improvement of existing ones. Its aims are long-term and its pursuit must not be unduly subject to the pressures of day-to-day design and production problems. But it must not be pursued in an atmosphere of divorce from these problems; and I would like to make a point which is by no means always appreciated by industrial research workers. It is that research in industry is not a thing apart, but something which, to be effective, must be woven into the whole fabric of the productive activity, and that it requires of the researcher experiences which cannot be gained in isolation from this wider environment.

I have learned at first hand that the research phase, though a vital one, is only a small part of the overall commitment involved in the process of translating a new idea into a reliable, efficient and economic piece of engineering equipment, and usually by no means the most difficult and responsible part. It can, of course, be an expensive part, and its adequate support, well ahead of an assured outcome, can make considerable demands on the finances of the organisation and on the judgment and foresight of its senior executives. And, it must be said, the achievement of a successful outcome demands, in the phase of manufacturing development and execution, the availability and the application of similar qualities of mind to those necessary in the research phase—and the closest collaboration, based on mutual respect, between the two sides.

The other aspect of my job has been that of trying to ensure that the young recruits to industry are adequately prepared by education and training for the changing situation which lies ahead of them. We senior members of the engineering profession have lived through a period of remarkable change—in the technique of engineering, in the range of engineering products and in the speed and directness with which the achievements of engineers have impinged upon communal life, both national and international; both at work and in the home. The pace of these changes has been quite fantastic; and there is no reason to suppose that it will slacken in the foreseeable future.

Being an electrical engineer, it is perhaps inevitable that I should approach my subject from this standpoint. I want to begin by summarising the achievements of electrical engineering during the past 20-25 years; then I shall comment on some of the consequences of these achievements within industry and in communal life; and finally discuss their educational implications, with particular reference to the domain of production engineering.

some recent achievements in electrical engineering

I think I can best illustrate the pace of recent progress by referring first to a number of developments which had either not been conceived or were in no more than embryonic, experimental form, 20-25 years ago.

First television, of which the early experimental transmissions were being made in the London area in the late 1930's. There are now in domestic use in the United Kingdom between 10 and 20 million television receivers; the pictures are black and white, but there is no major technical reason why they should not be in colour; the restraint is an economic much more than a scientific and technical one.

Secondly, there is radar, which was also in early experimental form in the late 1930's, just in time to prove of supreme value in the winning of the War, and now in widespread international use for air and marine navigation.

Then there have been developed to the stage of large scale manufacture electronic computers, devices for performing arithmetic calculations at incredible speed, which are being used extensively in scientific research, for the solution of complex problems of engineering design, for the routine design of electrical transformers and certain types of rotating electrical machines, for office accounting and as components in the control equipment of manufacturing processes. The latter is one aspect of the technique of automatic control, referred to as Automation, which goes beyond mechanisation by the replacement of human control by instrumental control, and leads to the prospects of the largely automatic factory for routine manufacture.

In the field of telecommunications, there have been developed various systems of world-wide communication, of which the most recent is the trans-Atlantic telephone cable, capable of handling 36 conversations simultaneously and incorporating amplifiers at intervals of 40-50 miles, lying in some cases at a depth of more than two miles. This is the first link in the plan to interconnect the Commonwealth by submarine telephone cable, unless, that is, the plan now becomes superseded by the prospect of world-wide radio communication by means of earth satellites.

All these types of equipment incorporate thermionic valves, except in so far as these are now being replaced by a tiny solid-state, semi-conducting, device, the transistor, which was discovered as recently as 1948, and which is not only much smaller in dimensions than even the miniature thermionic valve, but also requires much reduced voltage and current for its operation.

There have also been developed several major new scientific instruments of which the electron microscope, affording a resolution of a few Angstroms (10^{-8} cm) and a magnification of over one million times, and the mass spectrometer, now being used extensively in industry for the chemical analysis of gases, liquids and solids, are outstanding examples. To these have been added a whole range of high energy particle accelerators ranging from the 25,000 MeV. proton accelerator which came into use recently at C.E.R.N., the international centre for research in atomic physics in Geneva, to units providing 4 MeV. electrons for medical diagnosis and treatment.

Then as a concluding example, which illustrates perhaps best of all the pace of scientific and technological progress, there is the nuclear power reactor.

Within 17 years of the first, correctly explained, artificial disintegration of the nucleus of the uranium atom in 1939, a nuclear reactor, employing uranium fuel, was supplying 60 megawatts of electrical power to the British grid system. This station will soon be supplemented by several others of 300 and 500 megawatt rating now under construction in various parts of the country.

These are illustrative of recent, quite new, developments within the field of electrical engineering. They have been paralleled by considerable changes and improvements in previously well-established forms of electrical equipment, which though less spectacular and not so well known, have been no less meritorious. For example, during the same period, the size of turbo-generators has increased from 30 megawatts to units, now being designed, of 500 megawatts, and with this has been associated a decrease in the weight per megawatt rating by a factor of 3 and an improvement of thermal efficiency from 28 to 36%. Similarly the rating of high power transformers has increased by a factor of 6 and of the associated switchgear by a factor of 10.

some industrial and social consequences of these achievements

It is commonplace to remark that these achievements, taken in association with those additional ones which have occurred in other fields of engineering, have produced profound changes in man's mode of life, and that, while bringing great material benefits, they have raised considerable social problems. I now want to make a few remarks about some of the industrial and social consequences of the progress of automation, of the improvements in electrical communication, and of the advent of nuclear power.

automation

There can be no doubt that the concept of automation, particularly as it is sometimes presented by the public Press, has produced anxiety in the minds of many people employed in industry.

The normal result of the introduction of automatic methods into a particular manufacturing process is, of course, to reduce the number of workers per unit output of the manufactured product, and it is understandable that anxiety should be generated in the absence of an appreciation of the competitive necessity of the change, and unless the increased productivity associated with it, arising from reduced cost and improved quality, leads to an increased demand — a result which may not occur immediately.

This anxiety may not be restricted to those directly affected by a particular automatic installation. Inadequate knowledge of the financial problems involved in the management of industrial organisations, and of the limitations to the attainable rate of supply of automatic control equipment, may induce the belief, particularly if this is artificially stimulated, that the use of automatic devices will quickly become general and bring catastrophic changes in working conditions and in the security of employment. The fears of the individual will obviously be the greater the less his understanding of, and confidence in, the policy of the company employing him, and of the economic policy of the country as a whole; and the less he feels he can rely on the protection and support of his trade union.

Quite apart, however, from these considerations, he may have anxieties connected with personal concepts of possible new machines—with their seeming complexity, with the effort of adaptation he thinks they may demand, and with the work rhythm he feels they may impose. And even when these anticipatory anxieties have evaporated the readjustments made necessary for him by such characteristics of automation as reduction of manual effort and control, less personal contact with the product and a new type of, if not increased, responsibility, may raise personal difficulties. To these may be added a restriction on his freedom to communicate with his fellow workers, and a consequential sense of isolation.

The degree and seriousness of these various reactions will depend upon the adaptability of the workers concerned. To some extent this is a function of the individual character — human beings differ greatly in their capacity for accepting change and

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Sir Willis Jackson was educated at Burnley Grammar School and Manchester University. After lecturing in electrical engineering at Bradford Technical College he went to Metropolitan-Vickers Electrical Company Ltd. (now A.E.I. (Manchester) Ltd.) as a College Apprentice in 1929.

After a further period of lecturing at The Manchester College of Technology, he carried out research work for three years in the Engineering Laboratories at Oxford and then returned to A.E.I. (Manchester) as a research engineer. In 1938 he was appointed Professor of Electrotechnics at Manchester University and Professor of Electrical Engineering at the Imperial College of Science and Technology in 1946.

He rejoined the Company as Director of Research and Education in 1953, and will be returning once again to academic life in October, 1961, as Professor of Electrical Engineering at Imperial College.

Sir Willis has wide experience in both education and research and his guidance is sought by many outside bodies. He serves on a number of national councils and committees. He is also a Member of Council and immediate Past President of The Institution of Electrical Engineers, and this year's President of The Association of Supervising Electrical Engineers.

these differences are affected by age—but it is also a function of education to which I will refer later.

A further consequence of automation but of a different character which adds emphasis on this educational aspect, is the increased leisure which flows from it as a general trend. (I use the words "as a general trend" with some measure of personal interest, because I see little possibility of increased leisure for the members of the professional class.) I am bound to say I view with concern this consequence of automation for those many members of our community who reveal a disturbing ability to misuse the leisure time they already possess.

There is one other aspect of automation which I must mention concerning the underdeveloped—or, as I prefer to call them, the developing—countries. I referred previously to the need for increased demand as the most natural corrective to the anxiety of unemployment. Those of you who have visited countries such as India and Pakistan, and have had the opportunity to observe the discrepancy between their standard of living and the one to which we ourselves are accustomed, will be in no doubt about the enormous scale of the unsatisfied world demand for goods and amenities such as a more fully automated industry in this country would be in a position to help to satisfy. The problem is how to get these countries into a position where they can buy the goods and amenities they need and we could supply. There is no assurance, however, that in respect of consumer goods this is what they would do. It is more probable that they will seek to manufacture as many as possible of these goods themselves. This would mean that what they mainly want from us is the manufacturing equipment and the technical know-how of the manufacturing process, and these they will procure from us only if our equipment, techniques and advice, and the price at which we are prepared to provide them, compare favourably with those offered by other countries.

This raises another aspect of our educational problem; the production of an adequate number of high quality scientists, technologists and technicians.

electrical communications

We have now reached an international situation in which what is said and what happens, or is said to have happened, in any part of the world is known everywhere within a few hours.

This combined with the fantastic improvements in transportation have produced a degree of intimacy among peoples, the beneficial potentialities of which are enormous, but with the danger that it stimulates a hastiness of reaction and of judgment which may be seriously detrimental to international relations.

In particular it is bringing the common people of the developing countries into direct contact with the conditions and standards of life in the highly developed countries ahead of their ability to understand the differences in a rational way; is producing contrasts which are evidently of a disturbing character; and is accelerating changes which have taken centuries to evolve in the countries to which their attention is being so suddenly directed. In the words of Sir Eric Ashby: "Europeans have had little more than a century to adjust themselves to the shock of instantaneous communication and the shock is only now reaching millions in Africa and Asia, destroying centuries of tradition, driving society at a fresh pace. It is not sufficient to understand the technology which causes the shock; the shock itself must be understood too."

In our own homes the introduction of radio and still more of television, while no doubt bringing great benefits to old people and considerable educational possibilities for younger ones, is nevertheless generating a tendency for many towards the passive acceptance of information and of entertainment, and a withdrawal from more active, self-initiated, pursuits.

Taken overall, these improvements in communications have produced an international situation in which mass propaganda can be embarked upon without restraint, and there are times when I fear the consequences.

Here is an educational problem of great moment. Unfortunately to solve it for ourselves, if indeed we can do even this, will not suffice—we must strive to help others, who are as yet much more backward, to solve it also, and this will be a matter of supreme difficulty.

nuclear power

I referred earlier to the immense scientific and engineering achievement which, within a period of 17 years, transformed a small scale laboratory experiment leading to the artificial disintegration of the uranium nucleus into a large scale nuclear power station at Calder Hall, Cumberland, generating 60 megawatts of electrical power. The production of the first atomic bomb—the explosive form of the same nuclear fission process—however, took only five years.

I might have mentioned that hardly had the Calder Hall station begun to operate, and long before the nuclear power station had had a chance to establish itself as an economically competitive source of electricity, the physicists were acclaiming the early prospect of controlled thermo-nuclear reactions, the fusion of the small atomic nuclei of deuterium as distinct from fission of the large uranium one, as an alternative source of electrical power. When this is achieved, as it may well be within 50 years, it will make available unlimited power for unlimited time from the heavy water, D_2O, constituent of ordinary water, H_2O. Yet, again, the so-called hydrogen bomb —the explosive form of this same nuclear fusion process—has already been in existence, and in experimental use, for several years.

I might also have mentioned that the highly dangerous radioactive isotopes which are a by-product of these nuclear reactions are being used extensively for biological and agricultural research, for medical diagnosis and treatment, and in control systems in a variety of industrial processes.

Could there be a more striking example of the way in which the results of scientific research can be applied at will to both destructive and constructive purposes—in this case much the more readily to the former than the latter? And in the civil field, could

there be a better example of the manner in which concern for social consequences must form an integral part of the professional engineer's technical and administrative thinking and decisions? He must site his stations with due regard for local opinion on the amenities of the countryside, to the availability of water supplies taken in relation to other needs, to the transport of radioactive fuel elements and the disposal of radioactive waste products, to the possible effects of radioactive fall-out in the event of certain kinds of reactor failure, and to health precautions for workers within the stations themselves. It is probable that safety controls which have been incorporated in the design of the stations now in construction reduces the hazards associated with them to levels with are lower than those in existence in many other industrial activities. But it is not sufficient for this to be the case in fact; it must be known and accepted by the workers and general public to be so if unnecessary difficulties are to be avoided.

Engineering concerns the application of science to the needs of man. It is therefore inseparable from humanism. Could there be a better illustration of the proposition that the professional engineer is up to the neck in human problems whether he likes it or not?

some educational implications

I cannot hope to discuss fully the educational implications of the kind of scientific and technological developments to which I have referred, and of the social consequences which flow from them, but I will try to pin-point a few which bear on your sphere of engineering activity and responsibility.

at the professional level

It is, I think, self-evident that the pursuit of scientific discovery and of its technological exploitation cannot be restrained—not by unilateral decision of individual countries at any rate—and that if we, in particular, are to maintain our standard of living and our influence in the world at large, we must remain in the forefront of scientific and technological endeavour and achievement. This accounts for the great emphasis which has been laid during recent years on the need for a larger number of our most able young people to be attracted to the prolonged study of science and its applications. Estimates have been made of the increased annual output of scientists and professional engineers during the next decade, and our universities and colleges of technology are being expanded to cater for it. I do not propose to comment on these estimates. I am more concerned here with the nature of the education these young people should receive in preparation for the rapidly changing situation which lies ahead of them; and in this respect I shall refer only to engineers, with the needs of production engineering particularly in mind. The first aspect of this changing situation which I wish to mention is the growing interdependence of the various branches of engineering. Inevitably in the early stages of his career the young engineer must become something of a specialist. Equally inevitably, however, he will become a first-class specialist only if he is knowledgable about, and capable of appreciating the significance of, what is happening in other specialities which may come to impinge upon his own.

This requires that his educational preparation must be as broad as possible. I myself incline towards a common course for all engineering undergraduates during their first and second years, with subdivisions into civil, mechanical, electrical, chemical and aeronautical engineering deferred to the third year, and with specialisation within these main branches still further deferred until the post-graduate stage. The danger of too early specialisation is that the young engineer seeks to find the solution to his technical problems in terms of his speciality. For example, an electrical engineering graduate who has been permitted to concentrate on electronics in his final year will almost inevitably seek an electronic solution to a problem in automatic control, notwithstanding that it may be better engineering to use an hydraulic or pneumatic one. Breadth of undergraduate preparation seems to me to be particularly important for those who will later choose the production side of engineering work. I hope most sincerely that you will not press for the introduction of an undergraduate sub-division devoted specifically to this side, though I by no means mean by this that its importance and potentialities should not be drawn to the attention of students during this period.

Indeed, there is good reason why it should be. Not, however, in a technical sense so much as in illustration of the vital importance of human relations in the practice of engineering. Little of a formal character can perhaps be done at this stage, but what must be achieved is to open the mind of the student to the fact that exclusive devotion to a scientific and technical discipline will not give him all he needs in preparation for a career in engineering, and for life. Modern engineering is a major exercise in team work. Considerable scientific and technical knowledge are necessary for success, but by themselves give no assurance of it. An interest in, and the ability to resolve, human problems become of increasing importance, to all engineers; for those who choose to make their career on the production side, they are vital.

Many experiments in so-called liberal studies are being made in the universities, and they should be encouraged because they afford a valuable opportunity for breaking down inter-departmental and inter-faculty barriers. These experiments will be really successful, however, only if the teachers of engineering themselves provide a bridge by constantly referring to the humanistic aspects of engineering in the teaching of their respective subjects. And it cannot be over-emphasised that the most liberalising influence of all is probably that of active participation by the undergraduate in the corporate life of the student body. It is gratifying that the opportunities for this within the provincial universities are being enhanced considerably by the rapid growth of residential, and the considerable improvement of student union, facilities.

Movements in undergraduate courses in these directions will necessarily leave for acquisition at the

post-graduate stage an increasing amount of more specialist knowledge. As seen by some the best solution would be to increase the duration of undergraduate courses from three to four years. Fortunately, from my point of view, this step will be physically impossible during the next decade, since such expansion of our universities as will be achievable is likely to be fully absorbed in catering for the mounting number of young people, qualified for university entry, now emerging from the schools. For engineers, three years at a university is surely long enough preliminary to participation over a substantial period in the practice of engineering. This participation I regard as a prerequisite for the wise selection of a particular speciality within one of the main branches of engineering, and even more so for the selection of production engineering as a subsequent career.

The opportunity to gain a broad, basic, appreciation of the practice and organisation of engineering work is provided by well-planned schemes of graduate apprenticeship. This training is usually of two years' duration immediately following graduation and in my own company the second year is planned in close collaboration with, and is conducted under the sponsorship of, senior representatives of the functional activity which has been jointly selected—research, development, design, manufacture, etc. Contrary, it would seem, to the experience of some other companies, the manufacturing functions proves with us to be an attractive one to many of the best of our graduate recruits. Once well started, this is of course a self-propagating process, but it requires for its sustenance not only satisfying training and employment subsequent to selection, but also adequate preparation of the mind of the first year graduate apprentice for a kind of engineering work which follows less naturally than do research, development and design from his university preparation.

This may seem to argue for more specific attention to such subjects as workshop, technology and industrial organisation at the undergraduate stage. I see it more as a responsibility of, and a challenge to, the production side of the company to present their side as making intellectual demands which are no less severe, and as requiring men of no less intellectual calibre, than those of research, development and design—and as affording greater scope in the field of human relations. If an adequate number of good graduates are to be attracted to the production side, its senior representatives must be at pains to see that it is presented during the first year of graduate training as a progressive, stimulating and searching sphere of engineering activity, which demands the best and is determined to have them: and, having got them, they must be given ample opportunities not only to gain a varied experience, and a satisfying measure of responsibility as soon as possible, but also to broaden and strengthen their knowledge by participation in appropriate post-graduate courses.

In stressing the latter, I must make clear my appreciation of the limitations which attach to such of these courses as deal with management studies. The ability to acquire knowledge is one thing—the ability to carry responsibility and to exercise authority in relation to this knowledge is quite another. The only effective means of establishing that a man can carry responsibility is, of course, to put him in a position where he is obliged to do so. In no other way can he demonstrate the possession of certain essential personal qualities and abilities. When this has been demonstrated by success in one situation, it is a characteristic of good management that he will be tested and matured in others of greater complexity, with the advice and example of his more senior colleagues to guide him.

Nevertheless, a great deal of thought has been given during recent years to the question of what can be done outside the immediate environment of employment to assist this process. Is there a framework of general principles and a systematic body of knowledge about industrial organisation and management which, properly presented, will guide and assist young engineers the better to assess their personal experiences in this field? Can anything be done—in courses—to develop a man's ability to recognise and appreciate the significance to his own field of work of the activities of others engaged in related fields; to organise cooperative effort among men of whose respective specialities he may have only limited detailed knowledge; to draw reliable deductions from, and make sound decisions on inadequate evidence and in insufficient time; and to represent the views of other people, as well as to express his own, clearly and concisely?

Much has been written on these and other related questions, and many post-graduate experiments are being tried within the universities and technical colleges, and through the medium of staff courses organised by industrial concerns and public authorities. The anxiety attaching to the former, particularly where the students lack outside experience, is lest they may assume that successful participation in a course of study will automatically endow them with the qualities essential to good managers. It is of the greatest importance that this danger should be avoided.

Before leaving the professional grade of industrial personnel I must mention my strong attachment to the arrangement by which intending university students of engineering spend a year in industry between leaving school and entering the university. I wish this 1 : 3 : 1, or thick-sandwich, arrangement could be made more general. It brings to the university men of more mature outlook, much better able to appreciate the purpose of their engineering studies and the need for the pursuit of broadening interests; and it enables those who may not be suited to engineering work to transfer to another subject of university study without serious loss of time and with some gain in experience of life. The prerequisites are, however, that the scheme of training must be well organised and purposeful, and that it must provide for the continuance of scientific and mathematical study on a part-time basis of one day per week.

A further variant is provided by the five-year courses leading to the Diploma in Technology which

were introduced into our larger technical colleges some six years ago. Much, if not all, I have said about university courses applies to them with equal force, but what may prove to be of particular value to the production side of industry is the prospect of a much closer co-ordination of college study and industrial training. Although I hesitate yet to accept it, a case can undoubtedly be made for distinctive Dip.Tech. courses in Production Engineering. At least it is clear that here, more than in degree courses, is the opportunity to explore a more scientific approach to the subject of workshop technology; and great scope for experiment in presentation of the humanistic aspects of engineering work as an integral part of the scientific and technical studies. And what is even clearer is that the Colleges of Advanced Technology are in a particularly favourable position to conduct, in partnership with industry, advanced courses of a few weeks' or months' duration on specialist subjects relevant to the needs of their respective regions.

at the technician, craft and operative levels

National concern during recent years for our shortage of scientists and technologists has had the unfortunate consequence that the needs of the other categories of industrial personnel have received much less attention than they deserve. Too little recognition has been given to the fact that no new idea can be translated from the laboratory and design office into large scale production without the supporting skill and resource of a much larger body of technicians, craftsmen and operatives; and that the satisfactory education and training of the latter is no less vital to the successful operation of industry, and to the health of the national economy, than that of scientists and technologists.

I have little doubt that our shortage at the latter level arises in part from the fact that in the course of their work some of our professional people are performing duties which, with appropriate replanning and with the fuller use of computing and other new techniques, could well be undertaken by staff of lower academic qualification. This process of devolution is of course a quite normal one in progressive industry, but it requires for its progression the availability on an adequate scale of people who have been educated and trained in an appropriate manner. It is evident that this has not been occurring as extensively nor as rapidly as is desirable. Could the position be corrected quickly—which I doubt—it would, I believe, lead to a different assessment of the needs of industry at the professional level.

The most significant category of personnel in this connection is, of course, that of the technician, of whom the agreed international definition is given in an Appendix. So far the members of this category have come dominantly from promoted craftsmen and operatives, or from unsuccessful candidates for professional status. The technical college courses available to them have been mainly craft courses leading to certificates of the City and Guilds of London Institute, or those leading to the Ordinary and Higher National Certificates. It has long been evident, however, that the craft courses have afforded an inadequate foundation of scientific and technical knowledge and understanding for the prospective technician, while, in so far as the National Certificate courses have provided an important route to exemption from the examination requirements of the professional institutions, they have been too academic for the majority of the entrants to them.

In consequence the failure rate in National Certificate Courses, particularly in the early stages, has been extremely high, and the majority of those who have failed in them have withdrawn completely from further systematic study. In fact, few courses designed specifically to cater for the more practical requirements of technicians, to which they might have transferred, have been available, and even when such facilities have existed there has been considerable unwillingness to take advantage of them. What has been needed is a scheme of alternative courses, starting from school leaving age, which would permit a process of selection *upwards* into National Certificate Courses on *success*; not one of selection *downwards* into technician and craft courses on *failure*, leading all too often to selection of no course at all.

This is one of the objectives which the new pattern of courses for technicians, craftsmen and operatives, outlined in the recent Government White Paper "Better Opportunities in Technical Education", is intended to achieve. The general nature of the pattern is shown in the diagram (Appendix II).

A particularly important feature of the White Paper proposals is the aim to establish a minimum of 330 hours of day-time college attendance as the *standard year* for all these courses, of which in the technician and craft ones some 240 hours will be devoted to technical subjects and the remaining 90 to more general, including physical, education. The courses for operatives are intended to contain a larger proportion of general studies, but presented so as to bear closely on their vocational activities.

These are valuable steps towards the achievement of the County College concept of the 1944 Education Act. They will help not only to ensure in the young people concerned a more flexible and adaptable approach to changing situations in their work, but also to prepare them for more advantageous use of the increased leisure to which, as I indicated earlier, the progress of technical change in industry leads inevitably.

The White Paper deals dominantly with college arrangements, but it touches on four aspects of the contribution which it will be essential for industry to make if the desired result—that of a body of young people better prepared for participation in the changing pattern of industrial employment — is to be achieved. The first is close collaboration with the colleges and the examining bodies in the preparation of the syllabuses of classroom study and laboratory work for the new courses, especially for the technician courses. The second is a more widespread willingness to release young people for participation in continued education during the day-time. The third is intimate

co-operation with the staffs of the colleges in their selection of students for the alternative courses and the granting of appropriate recognition of their success in them; and the fourth, the provision of training schemes—organised and conducted by firms individually, or under group auspices, or in collaboration, in the early stages, with local or regional training centres—of adequate duration and standard.

It is all too evident that the educational plans being laid within our schools and technical colleges are not being matched by plans within much of industry for the effective practical training of its young recruits. Unless steps are taken as a matter of urgency to correct this unbalance, what is being attempted in the educational sphere will come to only partial fruition.

The seriousness of the situation may be judged from the following data, extracted from Hansard of the 22nd February, 1961, relating particularly to the entry of boys as (craft) apprentices and learners into the engineering, shipbuilding and electrical goods groups of industries in the years 1957, 1958 and 1959.

Boys entering Industry as Apprentices or Learners

	1957	1958	1959
(a) Engineering, shipbuilding and electrical goods ...	25,631	23,692	20,577
(b) Total entrants	95,184	93,212	98,701
(a) as % of (b)	27%	25%	21%

It will be seen that the number in these three groups decreased over the three years by some 20%. The total number recruited by the whole of industry increased by about 4%, but this small increase reveals a quite inadequate response to the appeals which have been made for industry to cater more effectively for the bulging output of young people from the schools.

With the above figures were associated the following statement of the outstanding role which the same sector of British industry played in our exports from 1957-1959:

Annual value of Exports (£ million)

Machinery other than electric	561.1	565.8	624.4
Electric machinery	227.2	221.7	231.3
Ships and boats	79.4	63.4	48.3
	(a) 867.7	850.9	906.0
Total exports	(b) 3325.0	3171.8	3330.1
(a) as % of (b)	26%	27%	27%

I feel bound to express anxiety about the maintenance of this position in face of the attitude which presumably lies behind the preceding apprentice recruitment figures.

Numbers are, however, only a part of the problem. I am one of those who are deeply concerned as to whether much that is called craft apprenticeship is worthy of this description. Conceivably, as my earlier remarks on automation may have implied, we can manage with a decreasing number of craftsmen. But if this is so, what is beyond question is that these craftsmen will need to be of the highest quality in skill and adaptability.

In this connection the time has come, in my opinion, for a radical reconsideration of our traditional concepts of apprenticeship—of its content and duration, and of the means by which it is conducted and financed. I am convinced that to age 18 at any rate, apprentice training should be treated nationally as an integral part of further education, and that until this occurs our problems in this respect will not be adequately solved.

My predecessor, Sir Arthur Fleming, used to say as long as 40 years ago, that the most valuable raw material of industry is its young people. Much has been achieved over the intervening years but we are still a long way from a general acceptance of this view. We professional engineers carry a heavy responsibility for ensuring that the young people who come under our charge are properly prepared by education and training, and by the example which we set individually, for satisfactory and satisfying participation in the rapidly changing situation which we are creating, and I trust we shall not fail in our fulfilment of this responsibility.

APPENDIX I

E.U.S.E.C. DEFINITION OF THE ENGINEERING TECHNICIAN

An engineering technician is one who can apply in a responsible manner proven techniques which are commonly understood by those who are expert in a branch of engineering, or those techniques specially prescribed by professional engineers.

Under general professional engineering direction, or following established engineering techniques, he is capable of carrying out duties which may be found among the list of examples set out below.

In carrying out many of these duties, competent supervision of the work of skilled craftsmen will be necessary. The techniques employed demand acquired experience and knowledge of a particular branch of engineering, combined with the ability to work out the details of a task in the light of well-established practice.

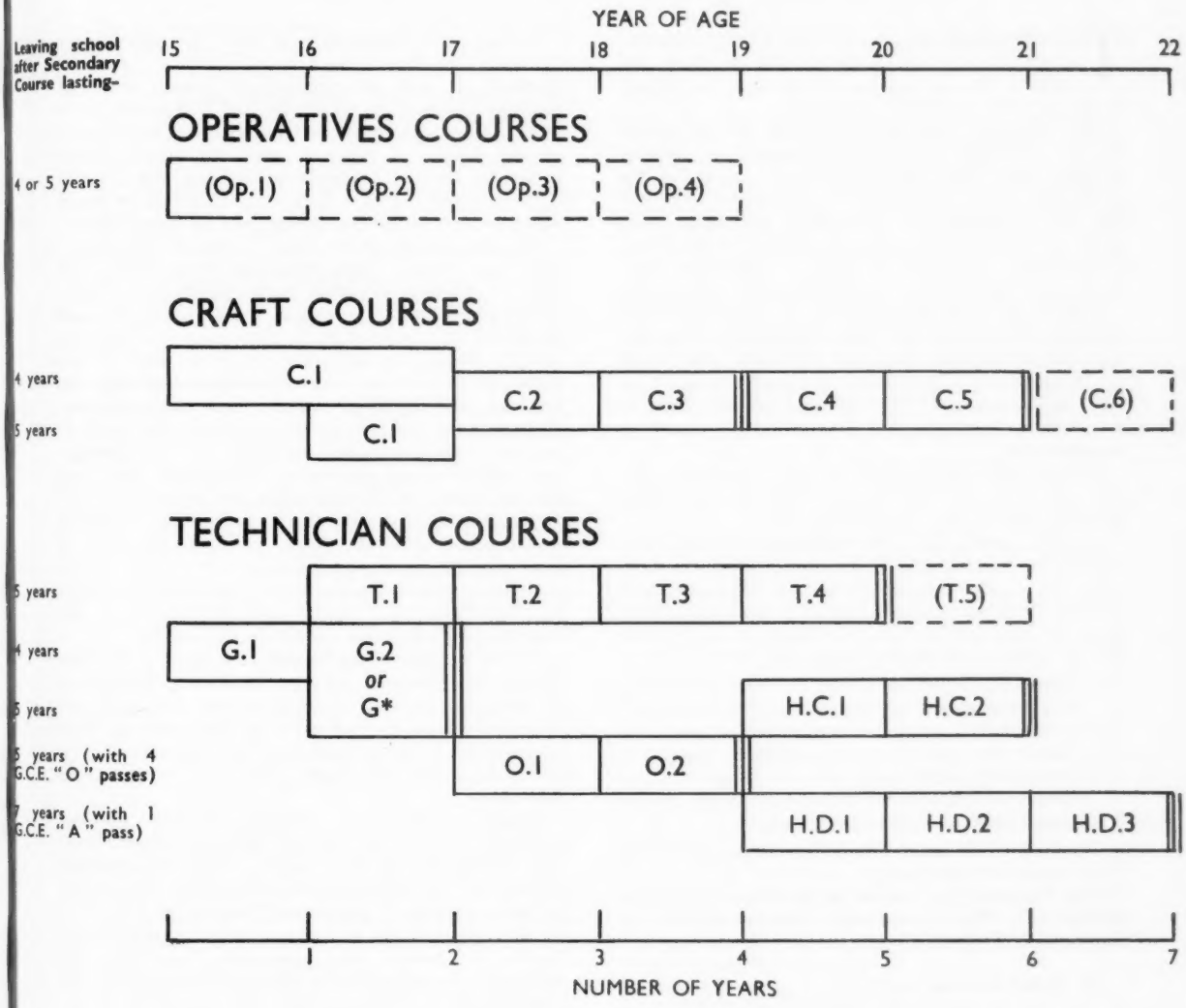
An engineering technician requires an education and training sufficient to enable him to understand the reasons for and the purposes of the operations for which he is responsible.

The following duties are typical of those carried out by engineering technicians:

Working on design and development of engineering plant and structures; erecting and commissioning of engineering equipment and structures; engineering drawing; estimating, inspecting and testing engineering construction and equipment; use of surveying instruments; operating, maintaining and repairing engineering machinery, plant and engineering services and locating defects therein; activities connected with research and development, testing of materials and components and sales engineering, servicing equipment, and advising consumers.

APPENDIX II

OUTLINE OF NEW PATTERN OF TECHNICAL COLLEGE COURSES FOR OPERATIVES, CRAFTSMEN AND TECHNICIANS.



Op—Operative Course. (These courses vary greatly in length.)

C—Craft Course.

T—Technician Course.

G—General Course

O—Ordinary National Certificate Diploma Course. (The Certificate Courses are part-time; the Diploma Courses full-time or sandwich.)

H.C.—Higher National Certificate Course (part-time).

H.D.—Higher National Diploma (full-time or sandwich).

|||—Denotes an intermediate or final stage associated with an examination.

*—Students leaving secondary school after a five-year course will normally take a one-year General Course.

Notes:

(1) Courses for Degrees, Diplomas in Technology or other qualifications leading direct to technologist status are not shown. Students gaining Higher National Diplomas or Certificates may also reach technologist status by further study; such further courses are not shown.

(2) This outline does not show all the possible routes open to the individual. For example, there will be opportunities for some students to transfer from a course of one level to an appropriate point in a higher course.

REPORT AND DISCUSSION

THE **President,** Mr. G. Ronald Pryor, extended a welcome to those attending the Meeting, and thanked the University authorities for making available such wonderful facilities.

The Viscount Nuffield Paper was one of several Papers established by the Institution to honour notable men who had done signal work for the Institution and the profession of production engineering. Lord Nuffield, in agreeing to his name being given to the Paper, had said he would like the Paper occasionally to have a wider application than those confined to the narrower aspects of engineering.

Lord Nuffield was President of the Institution from 1937 to 1939 and it had been largely due to his support and generosity that they had been able to set up the Research Department at Loughborough College, which subsequently developed into the Production Engineering Research Association, now sited in Leicestershire.

Tonight they were going to hear what was considered to be an outstanding Paper by Sir Willis Jackson, who needed no introduction.

A point which was not emphasised enough, and could not be emphasised too much in these days, when there was great emphasis on education, said the President, was that millions of pounds were being spent on new facilities for education on the technological front; and in his Paper, Sir Willis said:

> "Considerable scientific and technical knowledge are necessary for success, but by themselves give no assurance of it. An interest in, and the ability to resolve, human problems become of increasing importance to all engineers; for those who choose to make their career on the production side, they are vital."

Those two sentences should be engraved on all their minds for evermore.

The President then called on Sir Willis Jackson to present his Paper entitled 'Some Aspects of Engineering Progress".

Sir Willis Jackson expressed his great appreciation of the honour which had been accorded to him in being invited to give the Viscount Nuffield Lecture. He appreciated it more because he could not claim to have made any appreciable direct contribution to the kind of activities to which members of The Institution of Production Engineers normally devoted themselves; but he had had, during the last eight years particularly, the privilege of working in very close association with many men who had and he had formed a tremendous respect for them. On the whole, he thought that they had a very difficult job; it was the kind of job for which they did not collect too many of such bouquets as were being handed out.

It was very pleasurable to have the opportunity of delivering the Lecture in a University Lecture Theatre. It was an environment which was not unknown to him, in which he had had many humbling, though not he hoped humiliating, experiences at the hands of vigorous and inquisitive undergraduates. It was particularly nice that the Lecture Theatre should be in a University of which he could claim to be a Graduate, though not by direct labour.

His contribution in the field of research and education was several stages separated from theirs, but their respective domains had many close interrelationships which he would try to illustrate; and he would look forward in the discussion to a vigorous and, he hoped, critical commentary on some of the things he said, which concerned themselves with the kind of responsibilities which those inter-relationships imposed, not only on the education and research side but more particularly on their side—the production side. He was particularly concerned that they should analyse in the discussion the degree to which they were ensuring, by their schemes of education and training, that they were producing the kind of young person and generating in their young people the vitality, the enthusiasm and adaptability on which the well-being of industry and the health of the national economy was so vitally dependent.

He knew that in the Bristol area there were firms which were devoting a very considerable proportion of their resources to these objectives. He suspected that there were, in that area, as there were in most areas in the United Kingdom, many more firms who were not, and this gave cause for considerable concern.

Being an electrical engineer, it was perhaps inevitable that he should approach his subject from that standpoint and he wanted to begin by referring to some of the achievements in electrical engineering in the last 20 to 25 years, and then to refer to some of the consequences of some of those achievements; finally, he would raise questions concerning the educational implications of those achievements at the professional, technician, craft and operative levels. He had so much he wanted to say about the professional level that he had been afraid he might do what was so often done since the War—throw that into disproportionate perspective relative to the technician, craft and operative level. He hoped that the discussion would not unduly concentrate on the professional side.

Sir Willis Jackson then presented the Paper which appears on pages 569 - 577.

Professor A. R. Collar (*University of Bristol Department of Aeronautical Engineering*), in opening the discussion, thanked Sir Willis Jackson for a

most interesting and stimulating Lecture. He had had the privilege of reading the preprint and he assured Sir Willis that it had lost nothing in the oral delivery. He thanked the Institution for the privilege of being present and of being asked to take part in the discussion.

He found himself in a difficulty because he was wholly in accord with most of what Sir Willis had said. There was an old story of an American, a somewhat laconic individual with great economy of phrase, who, on being asked on his return from church, what the sermon had been about, summed it up in one word—"sin". Asked further what the minister had said on the subject, he summarised by saying "He was agin it". Professor Collar found himself on the other side of the fence—not in relation to sin!—but in relation to the gospel according to Sir Willis: he was all for it. Therefore, all he could do was to underline and emphasise some of the things he had said. Here he proposed to drop the formal "Sir Willis" and use the "W.J." by which the scientific world affectionately knew him.

remarkable progress

Referring to the quite remarkable examples W.J. had given of engineering advances in the electrical field, he was constrained to think of similar advances made in the aeronautical engineering field: such things as the gas turbine and supersonic flight, and possibly even space vehicles, if he could arrogate space vehicles to aeronautics. He was not speaking in any sense of competition but merely to emphasise in no uncertain fashion the quite remarkable rate of progress in engineering science in the past 25 years.

The theme developed had led W.J. to make a statement which needed underlining: that this country had to remain in the forefront of scientific and technological endeavour and achievement. He felt that the words "and achievement" deserved some comment. He had seen, in his own particular field, quite a large number of well qualified and very able young men, who had departed from Britain—quite recently one of his own graduates, who was beginning to acquire an international reputation. That migration had been largely because they had been denied the ultimate achievement. They had been able to stay in the forefront of scientific and technological thought, but the hardware at the end had been denied them.

It seemed to him that that aspect of engineering progress, the actual production on a large scale of good quality engineering products, produced cheaply, was one of the most vital things for Britain. This thought had led W.J., in his Paper, on to the subject of education. He was particularly interested to read the remarks in the Paper on the inter-dependence of engineering disciplines. Again referring to aeronautics, it was sometimes claimed that this was a specialised subject. Any aeronautical engineer would deny this assertion. Aeronautics depended very much on structural engineers for the economy in weight that was vital; it depended similarly on mechanical engineers for power units; on the aeronautical engineer and mathematician for the study of fluid mechanics, while electrics, both for control systems and flight operation, played a very important part. Aeronautics was, almost *par excellence,* an example of a discipline in which inter-dependence and interplay of all the branches of engineering played a vital part.

That was why he was particularly interested to see the suggestion that there ought, in university courses, to be at least two years of study on a common ground. He was sure that a great many engineering teachers would pay lip service to that; however, he suggested (perhaps with his tongue in his cheek) that of all the disciplines in engineering, electrical engineering tended to be the most self-sufficient. Electrical engineers had a tremendous lot to study in electrical technology, electrical power, electrical communications. They had a great deal to give, and other branches of engineering demanded a lot from them, but they seemed to find that some of the studies of other branches of engineering, such as the surveying which was necessary to a civil engineer, the fluid mechanics necessary to the aeronautical engineer,the structures and even some of the thermodynamics, were excellent training for others!

He would like to go along very strongly with W.J. on what he had said on the subject of liberal studies. There was, in schools particularly, still more than the lingerings of a belief that academic knowledge was divided sharply into Arts, Science and etceteras (and the greatest of these is Arts): while as a sort of appendage of science, if one could not keep it pure, was a subject called engineering. That was an attitude which was going, but it was still not recognised how very closely allied to the humanities engineering was, or ought to be. The engineer's job was to turn the findings of the abstract scientist into hardware which was going to be of use to and have an impact on humanity. That being the case, though science would inevitably form the bulk of his studies, there was no doubt at all that study of the humanities was as vital a part of the engineer's equipment for the job he had to do as was a study of science.

Professor Collar thought that history, particularly the history of science, but also social history, was one of the most important things that was required for study by an engineer, but also he had got to be able to understand other people from other countries; he had got to be able to communicate with others in a lucid and literary form.

importance of communication

Those things were of prime importance, but there were lots of others, and—*ars longa, vita brevis*—it might well be that some selection from among them was going to be necessary.

Finally, on the comments about production engineering, he echoed W.J.'s belief that production engineering should not be asked for as an undergraduate study in universities. He did not think it was appropriate, very largely because, if an engineer was to be a real student of a university, and to get from the university everything that was possible in the way of contacts with other students, then he had to be a normal student for the continuing three-year

period, and his contacts with industry were going to be slight; he did not believe that, at the undergraduate level, contacts with industry were sufficiently good to allow an undergraduate to absorb what was necessary for production engineering. It was rather like a suggestion that dentists should be taught about teeth on a blackboard with the aid of diagrams; a dentist had got to get out and look people in the mouth in order to find out what he was going to do. Similarly, the production engineer had got to have active contact with industry during the course of his studies.

That meant that, so far as universities were concerned, at best production engineering might come at the post-graduate level. Even there, it might possibly be difficult and he would like to see the post-graduate period of training in industry, the graduate trainee period, given a heavy slant towards production engineering, because that was where it should come and where it was very necessary. Those two years corresponded, he supposed, to the clinical years of medical training, and were very necessary for all engineering students who were really going to acquire competence in the subject.

While on the subject, he wished to underline what was said in the Paper about the 1 : 3 : 1 sandwich scheme. He was wholeheartedly in favour of it. If he could get all his students as engineering apprentices from industry, having spent a year in industry, he would take them all that way. As it was, a good deal more than half of his students came in that way and there was no doubt that the student who had had a year's training in industry went to the university knowing far more what it was all about, and had a maturity of outlook and a sense of purpose which was not in the schoolboy; for that reason, he could give more to the university and certainly gain a lot more from the university.

Turning to the Diploma in Technology, Sir Willis was a member of the National Council on Technological Awards, of which he had himself had the privilege of belonging since its inception; in the Diploma of Technology, Britain had a most remarkable opportunity which should not be lost, of insisting on improvement in instruction in production methods. When the Diploma had first been mooted, and when Lord Hives undertook to set about putting the wheels in motion, it was suggested that it had to have the standard of a university honours degree. He remembered, at the first meeting, asking permission to read a sermon to his colleagues on the vital need to make the new courses for the Diploma in Technology something different from university courses, if for no better reason than that university disciplines and degrees had been in existence in Oxbridge for ten centuries, and in many other places for the best part of a century, and if the Diploma courses were common in content and outlook, all good students would opt for the university, which would be a tragedy. Many excellent students now going to universities would be admirably suited for what might be described as the more practical outlook associated with production methods, and since this country needed production engineering more vitally than it needed anything else, and since a new form of training had been set in motion, for the good of both there should be a slant towards production engineering in the courses for the Diploma of Technology.

Since he was talking of the Diploma in Technology and of Lord Hives, he would remind them that a few years earlier Lord Hives had addressed the Institution in that same room, and in the course of his address had told a story. Two firms in the Midlands producing very similar articles had always been friendly competitors and had jogged along together pretty well, until it became apparent to Firm A that Firm B was beginning to forge ahead and produce a better article, and also to undersell Firm A. Firm A had a board meeting and told one of its members to go and find out what it was all about. Since the firms were friendly, there was no difficulty. The man went along and inspected the works, and returned and made his report. He said: "I don't understand it. There is no doubt whatever that they are producing a better article and more cheaply. And what's more, they are doing it in spite of the fact that they have got an adjectival graduate every 50 yards".

The time was fast coming, if it had not already arrived, when Lord Hives could retell the story, not about the graduate, but about the Diplomate in Technology.

Mr. F. W. Cooper (*Education Officer, Institution of Production Engineers*) said that he would anticipate the Editor's remarks, when the Proceedings appeared in print, by saying that the views of the Institution did not necessarily coincide with the views of its Education Officer.

Sir Willis had said that he sincerely hoped that the Institution would not press for an undergraduate sub-division in production engineering. With equal sincerity, Mr. Cooper entirely disagreed with that.

He might be accused of supporting a three-year undergraduate scheme; he did not do so. What he wanted was a five-year undergraduate scheme of which at least one-and-a-half years would be spent in industry, sponsored by the university, and three-and-a-half years in the university. He wondered when the universities would do some simple arithmetic and add three years' undergraduate work and two years' practical training and similarly get five years.

Sir Willis seemed to place the emphasis of the training on post-graduate practical training in industry. With a few exceptions, it must be faced that today the average post-graduate training in industry was most dismal. Often, to bolster up the work, the graduate was sent to a technical college for a 12-week course of appreciation of production engineering. Mr. Cooper suggested that that was straining the word "appreciation" a great deal.

Sir Willis had also mentioned post-graduate courses in universities. He suggested that there would be very few young men who would persuade themselves, or the firm, that they should go back into a

university for 12 months; even when they had done that, fewer would find the money to do so. Having solved those problems, what did they find by way of provision in the way of production engineering? He suggested, very little. Having disposed of that, he would refrain from asking why an undergraduate course in chemical engineering was more respectable than an undergraduate course in production engineering. He would rather say, why was the undergraduate course in chemical engineering more useful to industry in this country than an undergraduate course in engineering production?

Why was it that in the last two years of a course some subjects were not considered academically respectable? He believed metrology was just as respectable as surveying; he believed the study of the kinematics of a machine tool was as respectable as the kinematics of the obsolete steam engine. He suggested that tool design was just as respectable as some of the queer things he saw being done in machine design.

Was it that they did not like production engineering subjects suddenly appearing in the third year? All he asked was that, parallel with the study of human relations, which he considered utterly essential (and for the mention by Sir Willis of this he was grateful), there should be some production processes in the first year; and could they not have a slightly different type of mathematics—a slant towards statistics and probability? Could they not have "oilantics" rather than the flow of water over a V-notch? He did not very much mind whether it was called a first degree in engineering production, but suggested that there was room in Britain for such work and there was no time to waste if we were going to hold our place amongst the industrial giants who firmly believed in such work.

Mr. E. G. Sterland (*Principal, Bristol Aircraft Company Technical College*) said that in one or two passages in his Paper Sir Willis Jackson had betrayed some disquiet over one or two particular problems of the day. He himself could discern one or two others to which he wished to draw attention.

The first arose out of the first part of the Paper, where reference was made to the tremendous rapidity of the progress in the last 25 years. Today, it was not too much to claim that we stand in a position, in science and technology, where the answer to virtually any problem could be found; not the answer to every problem but the answer to any problem and that was an important distinction, because it meant some selection had to be made between the range of problems one would like to have solved. In certain areas, for instance atomic energy and aeronautics, the cost of solving these problems was so great that it was beyond the purse of any private company to embark on their solution unaided by Government assistance. Some decision had therefore to be made by a Government department as to which problems should be tackled and in what order, so that finance could be made available.

The aspect of this situation that worried him was that the people who were making those decisions were very often themselves not engineers or scientists even remotely connected with the subject, and they knew very little indeed about the actual technical problems involved at first hand.

It might be said that that did not matter; that to be a good administrator all one needed to have was intelligence and a mind trained in some way, preferably by taking a degree in Greats at Oxford. He did not know whether Sir Willis would agree, but he regarded the study of the Classics as one of the biggest educational red herrings that had ever been drawn across the educational scene. It might be said that because someone who had attained great distinction had read Greats at Oxford, that this had produced a brilliant intellect; that was not necessarily true. He would have had a brilliant intellect whatever he read and wherever he read it.

Sir Willis had been worried in case industry would not be able to absorb the large numbers of engineers and technologists produced at the end of the decade. He need not worry about that. Let them be put into the Civil Service, and let there be a few Parliamentary Private Secretaries who had degrees in engineering, to talk the language a bit.

employment of graduates

With regard to the employment of graduates in production engineering, there were people who regarded that as being an unnecessary expense, and possibly as being merely a method of "keeping up with the Jones's". Because A had a graduate, B ought to have one too. People tended to overlook the fact that the people they now looked to, in senior positions in engineering, in engineering management, in production engineering, who had got there by what was called the "hard way" and possessed no technical qualifications, would, if they had been born 30 years later, have had much greater opportunities and would undoubtedly be in possession of university degrees.

In apprenticeship training schemes, craft apprentices of low academic calibre were deliberately introduced and provision made for the best to be promoted to a higher grade of apprenticeship if their academic ability justified it. Those who remained craft apprentices until the end of the five-year craft apprenticeship were, therefore, limited in potential.

Could it be expected that, from the skimmed milk of the craft apprentice, future works managers could be produced? That was clearly not going to happen again in the future and, for that reason, graduates had somehow to be introduced into the production side of the business. It was particularly important in firms where there was unbalance caused by a preponderance of highly trained technical manpower on the technical side, with a paucity of technical people on the management side.

Mr. Sterland saw a bogey which he would couple with Sir Willis's remarks on the use of leisure, although it was rather oblique. We were in danger of creating a "technocracy" or an "I.Q-ocracy". We had an educational sieve: there was a sieve at the

11-plus examination; there was a sieve at G.C.E. "O" level; there was a sieve at G.C.E. "A" level; there was a sieve at degree stage. The more intelligent penetrated to the bottom of the sieve and the others got caught up at various levels.

What had been done was comparable to what Aldous Huxley suggested might happen in "The Brave New World". That book, written in 1928, was worth reading. He described a situation which could exist in the second century A.F.—meaning "After Ford"—where it had been discovered that it was no longer necessary to go through all the processes which were carried out to reproduce the human race. In other words, it could be done in bottles, the contents of which could be worked upon by chemicals and by radiation to produce the kind of human being that was wanted.

They produced a few Alpha pluses; but they recognised that the world would not work if everyone was highly intelligent. They therefore produced a number of Dip. Techs.—good solid people—some betas and beta pluses, right down to the deltas and epsilons who could do the manual jobs. They recognised that it was necessary somehow to produce a balance of people. They were in danger of creating a brave new world by the sorting process rather than by any deliberate attack on the unborn embryo as in the "Brave New World" of Aldous Huxley.

Thirty years ago, if a man did not succeed, he could say to the world and his friends, and most importantly to himself: "I didn't succeed because I did not have the opportunity". He could not say that today. The opportunities were there. He had to say: "I am not succeeding because I am not good enough". That was a dangerous situation. It was an educational problem. Mr. Sterland did not know the answer to it.

He supported what Sir Willis had said about craft apprenticeship, but in somewhat stronger terms. If a visitor from Mars came to earth and was told about craft apprenticeship, he might ask: "Is it, in your system, necessary that for every craft there should be a five-year training period?" The answer would be: "Yes, it is in the 1944 agreement". He would say: "But surely, this is rather extraordinary? Isn't it possible that some jobs might take three years to learn and others seven? What about the boy who learns faster? Isn't it possible that some trainees might learn in four years a craft that an average boy would take five years to learn? What do you do about him? What about the boy who takes longer to learn a craft?" The answer would have to be: "The five-year period is a sort of sacred cow and everybody has to do it". "Then how would you ensure that these apprentices do actually learn anything?" It would have to be confessed that there were no methods whatever of determining that; all the boy had to do was get five years older, someone signed a paper and gave it to him and he automatically became skilled. There were no syllabuses and no tests at the end of the five years. There was no definition of skill and the whole thing was unscientific. He was forced to strong agreement with Sir Willis's views that, up to the age of 18, it ought to be taken over and run by the education authority.

Mr. C. P. Horstmann (*Deputy Works Manager, Horstmann Gear Company Ltd.*) asked Sir Willis to give some guidance on the matter of day-release for students and craft apprentices. It was perhaps an exaggeration to say that companies were not willing to give day-release. Most engineering firms gave day-release for apprentices quite willingly but were finding it increasingly difficult to do so, because with modern machine tools the capital value behind the operator might be very high. They could not always afford to put an apprentice on a machine which, with measuring equipment, could often have an installed value of £10,000, and have one day idle in the week. If the working week was going to be still further reduced, the problem would increase rather than decrease.

Had anyone any solution to the problem, bearing in mind that a company was willing and agreed with the principle of day-release, but found it difficult?

Mr. W. Saxton (*Bristol Siddeley Engines Ltd.*) said that he had no criticism of the Paper at all and was extremely indebted to Sir Willis for producing it. It contained much wisdom and was a great help to everyone to have day-to-day problems and possible solutions indicated in such an admirable manner.

Sir Willis had asked how one got over the industrialist's problem to the teaching profession. He had given the answer himself. Having read the Paper and learned something of the author's background, he saw that Sir Willis had wandered quietly into industry and out of industry. He complimented him.

Mr. Saxton's firm had 1,250 apprentices with 24,000 employees, which were the same figures as Sir Willis's company. He was a little concerned as to whether or not they had too many. The difficulty was to keep them interested, and he was quite worried that they were giving the apprentices a bad start because people were so preoccupied with their jobs that the boys got a bad impression of industry and were not either being trained or working. He did not know the solution.

He agreed that there should not be production undergraduates, but he felt that undergraduates should understand more of what the production side of the industry had to offer, particularly with the problem of human relations, etc. That might be industry's responsibility.

The problem was now attacking the engineering and the higher professions. Bank managers were going on strike. Things they had had to live with for years, as society got more organised, would rear their heads. Sir Willis had drawn a distinction between production and engineering, but Mr. Saxton felt this was a little invidious and did a disservice to industry as a whole.

On the question of 1 : 3 : 1, Mr. Saxton was in entire agreement that this was the right thing for the man who was going to be trained as a professional engineer. The Dip. Tech. was a very poor

second indeed. He did not think, with limited knowledge, that it was living up to the great hopes Sir Willis expressed.

He thanked Sir Willis for his excellent Paper.

Sir Willis Jackson, replying to Professor Collar, said that when remarking earlier that they must move in a direction of having the first two years of university engineering courses common, he had not meant that one would add together in the second year the convenient bits of existing engineering courses. He doubted whether the university teaching of mechanical engineering reflected anything like adequately the changing situation in respect of materials and in respect of the atomic and molecular basis of thermodynamics. Therefore, when he had said that he would like electrical engineers to do more mechanical engineering, he would want that mechanical engineering to reflect adequately the changing foundations of the subject.

In drawing comparisons between university courses and Dip. Tech. courses, the easy thing to do, particularly for the university staff member, was to comment adversely on the Dip. Tech. course by saying that they compare too closely with university ones. He had a hunch that it might be wise to leave the Dip. Tech. courses more or less as they are for the present, and to embark on a searching reappraisal of the university ones.

In respect of liberal studies, he was not aware of a really critical attempt within the universities to decide what they should be from the point of view of undergraduate engineering education, and what part the Arts Faculties should play in them.

He agreed very strongly with Professor Collar's hope that Colleges of Advanced Technology would pursue the sandwich course experiment, but was afraid that some of them would prefer to fall back on the university pattern. Speaking of his own firm, he said that they were now sending about 250 boys to Dip. Tech. courses. Unfortunately, these courses were so arranged that the whole of the students were loaded on to the factory at one time of the year for a period of three months, and off-loaded at another. The Company would like, both for its own benefit and as a further contribution to the national situation, to increase the number of Dip. Tech. students to about 450, but it was quite evident, as had been touched upon by Mr. Saxton, that this would be impracticable unless the college concerned could so modify the course structure as to avoid severe unbalances in the loading of the training facilities of the factory. He accepted that this would probably involve a lengthening of the courses from four to five years.

workshop technology

The subject of workshop technology seemed to him to require urgent consideration. This could not be done unless men who were experts in the production field were willing to devote some part of their time to thinking out the scope and content in relation to the evolving manufacturing situation and how it should be presented. It seemed to him essential, and not only in this particular field of technology, that carefully selected men whose primary employment was in industry should be given high academic status in the universities and Colleges of Advanced Technology to assist in the formulation and the conducting of post-graduate and post-Dip. Tech. courses. Courses of the standard required could not be achieved wholly by men occupying full-time teaching posts in educational institutions. This arrangement was common practice on the Continent and in Russia. In a recent visit to the Technische Hochschule in Delft in Holland, he had found that about a third of the professional staff were employed in industry and spent either one day per week or a block period from time to time in the Hochschule. His impression was that these men made a vitally important contribution and undertook it as an integral part of their industrial responsibility. It was not easy to say who should take the initiative in the matter in Britain. There were undoubtedly safeguards to be applied and the demands on the selected people would undoubtedly be heavy.

Dip.Tech. courses

A further point raised by Professor Collar, that perhaps the Dip. Tech. courses could be given a slant in the direction of production, was an important one, but involved the assumption that one could sort out boys of 18 years of age appropriately. Could that be achieved on evidence available merely from the schools? The suggestion argued strongly for a year in industry prior to a decision as to whether a boy should go to a university or to a Dip. Tech. course at the end of it. This would demand the most intimate liaison between university and college staffs and industry if satisfactory selection was to be achieved, and one aspect of the urgent need for a closer partnership between these bodies.

He was pleased to hear what Mr. Cooper had said but disagreed with him. He did not see how one could expect a youngster going to a university straight from school to have any basis whatsoever for making a selection in favour of production engineering or be wise enough to attempt to do so.

He had mentioned in the Paper that he thought the production side of industry had by no means yet presented itself to the graduate as requiring men of no less intellectual calibre than research, development and design, and as affording greater scope in the field of human relations. He would ask Mr. Cooper whether the Institution had done all it should to portray production engineering to graduates as a progressive, stimulating and searching sphere of engineering activity? It would be unwise to attempt to impose educational objectives on the universities until this more direct responsibility had been fully shouldered.

Mr. Sterland had touched on the question of whether scientists and technologists should be playing a greater part in making policy decisions. It was easy to be critical of Government establishments and

the public services and to say they were taking decisions and seeking to organise matters within their central organisations that would be better left to be organised by industry. But if industry did not do this, it could not justifiably blame others who, recognising national deficiencies, took steps to correct them—though they might take wrong decisions in doing so. He also hoped that more scientists and engineers would begin to enter public life, but it might be an assumption to suppose they would be wiser than the present people. At least, however, their background would be more appropriate to the needs of the evolving situation.

Mr. Horstmann had raised the question of day-release. The solution to his problem might be to adopt block-release arrangements, as his own firm had done in Manchester.

Sir Willis said that it was too early for Mr. Saxton to make an advance judgment on the Dip. Tech. scheme. It afforded a great opportunity for experiments in collaboration between the colleges and industry. Industry's responsibility for the quality of the products was no less than that of the colleges, particularly where the boys concerned were industrially based.

Mr. F. G. C. Sandiford (*Chairman, South Western Region of the Institution*), moving a vote of thanks to the speaker, said that Sir Willis's work had made them all see the new educational problems much more clearly than they had before. From time to time, those in industry needed to be reminded of their responsibilities for training up those who were following them. He was sure everyone present would like him to say how privileged they had been to hear the results of some deep thinking on the subject, by someone who had clearly had considerable experience of education and industry, and who also showed a very sensitive understanding of the complications which were facing present-day graduates as well as industry.

He found great comfort in the thought that there were men like Sir Willis at the top of the educational tree who were worrying about those things and finding time to point them out.

Most of those present would realise the amount of work that went into the preparation of a Nuffield Paper of the calibre of that which Sir Willis had given, to say nothing of the difficulties of getting away from business, but the attendance of so many important industrialists and educationists from the West Country was perhaps sufficient in itself to show that the interest of the engineering industry in the area was in what Sir Willis had to say to them. He hoped that Sir Willis would feel that that interest had made his visit worthwhile.

On behalf of all present, he had the pleasure of saying: "Thank you very much for coming and for giving us such an educational evening".

The vote of thanks was carried by acclamation, and Sir Willis Jackson was presented, by the President of the Institution, with a silver rose bowl as a memento of the occasion.

The proceedings then terminated.

FIVE THOUSAND TAKING DIP. TECH. COURSES

The Chairman of the National Council for Technological Awards, Sir Harold Roxbee Cox, in a foreword to the recently-issued Annual Report of the Council, states that the year 1960/61 has been notable not only for the large increase in enrolments for the Diploma in Technology, but for the gratifying number of registrations for Membership of the College of Technologists (M.C.T.) in the first full year since its inauguration.

The Report, which covers the period April, 1960 - March, 1961, shows that nearly 5,000 students were taking courses in the Diploma in Technology, compared with 3,800 the previous year; nearly 1,770 students, including 63 women, had enrolled in first year courses compared with 1,500 the previous year (of whom 40 were women); over 470 Diplomas have been awarded; and 34 applications for the M.C.T. had been received, of which 27 had been accepted and five were under consideration.

The Report says that the total number of students taking Diploma courses and the number of Diplomas awarded is "quite a remarkable achievement over the five years the Council has been in existence". The Council pay tribute to the enthusiasm with which colleges and industry have embraced the concept of the Diploma in Technology.

PLASTICS IN ENGINEERING

by A. J. J. MOULAM

Plastics Department,
I.C.I. Ltd.,
(Northern Region)

Mr. Moulam has been with Imperial Chemical Industries, Ltd., Northern Region, since he graduated from Manchester University in 1952 with a degree in Electrical Engineering. He was engaged first in the Engineering Trades Sales Department and is now a representative in the Plastics Department, particularly concerned with extrusion.

This Paper is based on a lecture given to the Preston Section of The Institution of Production Engineers in 1960.

IT would be easy to give a list of applications in engineering for different plastics, but it would have little significance until the reasons for the choices were explained. A better approach is therefore first to find out what a plastic is and how it behaves; next to consider some of the more important specific materials; and to finish off with a description of the methods used to manipulate plastics. With this background some actual jobs done by plastics in engineering can be outlined, almost as an appendix.

At the end of the 1914-18 War there were only a few plastics commercially available. They included cellulose nitrate, casein and phenol formaldehyde resins and moulding powders. Soon the list was to be augmented by urea moulding powders and cellulose acetate, but now so many materials are available that engineers, and indeed most other users, need help and advice to decide between them.

The Second World War made immense demands on raw materials, both natural and synthetic, and great efforts were made to produce new ones. Acrylic sheet for aircraft canopies, and polythene—which virtually made radar possible—are examples of two of the most successful contributions of the plastics industry. When the War ended considerable ingenuity was displayed in devising uses for the now surplus production, but unfortunately many things were made from unsuitable materials. Little wonder that inflammable ashtrays and easily torn raincoats led to the idea that plastics were substitutes for the real thing. Nevertheless, their inherent worth enabled

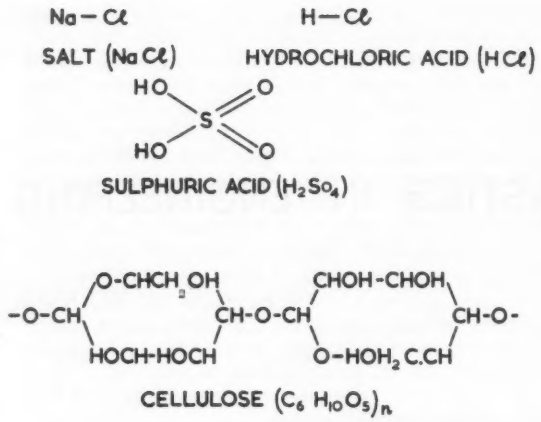


Fig. 1.

them to survive the criticism and now one can hardly contemplate any sector of business where they do not play a valued part. Indeed, at present manufacturers are so hard pressed to satisfy all demands, that extensions and modifications to existing plants are being made whilst the building of new ones is pushed ahead as quickly as possible.

nature and structure

But what are plastics? As the name implies they are materials which at some stage in their existence become plastic, and so can be moulded into finished shapes. Heat and pressure are usually needed to make them flow, and when they do they retain many of the attributes of solids. This behaviour is familiar as that of heated amorphous structures, whereas crystalline materials melt suddenly and become liquids. With plastics however the position is somewhat different, as some of them are wholly amorphous, some of them are virtually wholly crystalline, and some are partly crystalline and partly amorphous. The high viscosity of the heated material, irrespective of its original crystallinity, is a consequence of the fact that the molecules of plastics are very long indeed and so become highly entangled with one another.

Instead of simple molecules like those of salt or hydrochloric acid consisting of only two atoms, or even the comparatively large seven-atom structure of sulphuric acid, plastics molecules are giants with thousands of atoms, arranged in long chains. The backbone of the chain is carbon, which is the essential element in many of the raw materials from which plastics are made. Long chain molecules also exist in nature and substances like bitumen, shellac, rubber and cellulose are examples (Fig. 1). The origin of the plastics industry may be traced to efforts to modify one of these molecules nearly 100 years ago. Alexander Parkes, a Birmingham chemist, discovered that nitrated cellulose could be made more workable and useful if it was mixed with camphor. The Hyatt brothers in America, independently, at about the same time, made the same discovery and their invention has become universally known under the name of "Celluloid".

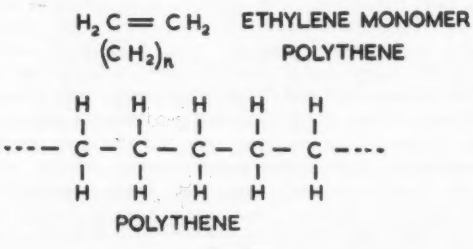


Fig. 2.

The next step was to build desirable chain molecules artificially from simple short ones. In this way truly synthetic organic chemicals are produced. An example of the technique was the preparation of phenol formaldehyde moulding powders in 1916 following work by Baekeland. "Bakelite" found many uses in industry and, as a measure of success, the word bakelite is nowadays used more as a generic term than as a trade name. Similarly polythene is the result of persuading the ethylene monomer $CH_2 = CH_2$ to polymerise to $(CH_2)n$ (Fig. 2).

Distinction must now be made between the two classes of plastics, THERMOSETTING and THERMOPLASTIC. During processing (i.e. heating to the curing temperature) thermosetting plastics become permanently set, insoluble and infusible, whereas thermoplastics can be softened by heating and hardened by cooling almost indefinitely—at least until the material burns or degrades.

It is an over-simplification to regard the molecules forming a plastic as simple chains, as in fact they are often branched. In a thermosetting material the branches, on curing, join on to other molecules to form a rigid three-dimensional structure, so that an article made from a thermoset is virtually one large molecule. This phenomenon is called cross-linking.

effects of structure on properties

One of the differences already mentioned between plastics and metals, which have small molecules, is that the latter melt rather than soften. This is because when heat is applied it overcomes the relatively small cohesive forces so that the molecules can separate and become free, as in a liquid. With plastics, however, although heat reduces the forces of attraction between neighbouring molecules, they remain entangled with one another, and although in a hot plastic there can be some relative movement between molecules, they are still not completely free of each other.

In a similar way the addition of solvent to a plastic pushes the molecules apart, thus reducing the cohesive forces and making the material first soft and rubbery, and eventually producing a solution. This is a useful effect and non-volatile solvents called plasticisers are often used to modify the properties of plastics. Thus

polyvinylchloride can vary between a rigid solid when unplasticised to a paste of a low viscosity.

When subjected to tension, chain molecules are at first firmly anchored to one another by the cohesive forces and uncoiling of the long molecules takes place. This is an elastic deformation. When the forces are finally overcome the chains slide over one another until many ends come together and the test piece breaks. From the foregoing, one would expect the tensile strength of a material to be proportional to the molecular weight (or chain length) and this is roughly true.

It is sometimes regarded as odd that plastics exhibit such a wide range of toughnesses, from glassily brittle to almost unbreakable, but the same sort of spread is shown by cast iron and high tensile steel. The explanation with plastics is that when the molecular structure is such that the molecules are relatively free to move over each other, shocks are easily absorbed, whereas when the geometry of the molecules prevents easy relative movement or the chains are bound to each other by cross-linking, they cannot "ride a blow" and the material then breaks under impact.

Specific examples of the way difference in structure affects properties are shown by polythene and polyvinyl chloride (p.v.c.). The former is a simple hydrocarbon and it is affected by few chemicals, but p.v.c., because its molecule is unbalanced by a relatively large chlorine atom, is attacked by organic solvents. Electrically, polythene has a balanced molecule and is an excellent insulant, but p.v.c. has an unbalanced molecule because chlorine is of opposite polarity to hydrogen, and p.v.c. is therefore a less good insulant than polythene—particularly at high frequencies.

Thus geometry and chemical make up affect considerably the properties of a substance, and with synthetic molecules we are able to produce materials with attributes more or less as desired. The chemist controls chain length and branching, the arrangement of the components of the molecules and of course the chemical composition. This means that for a particular requirement a material can be tailor-made, within the limits of the general nature of plastics.

chemical properties

Plastics are in general inert, polytetrafluoroethylene (p.t.f.e.) particularly so, being attacked only by molten alkali metals and fluorine. Resistance to alkalis and acids is usually good but organic liquids often have a solvent effect and are therefore used as plasticisers. Nylon is the exception to this generalisation, as it is unaffected by most organic substances and alkalis. Its disadvantage is that it absorbs relatively large amounts of water, which other plastics do not, hence its dimensional stability leaves something to be desired in conditions of varying humidity.

Ultra violet light tends to degrade plastics by oxidation, so for good weathering properties carbon-black has to be incorporated in order to protect the material. This does not apply to acrylic sheet, which is used for lighting fittings and signs as its weathering resistance is excellent. The exposure resistance of other plastics is not as good as this, but can still be very good.

As implied, plastics have little effect on other materials, particularly at normal temperatures. Nevertheless, one or two combinations of materials have to be avoided at high temperatures—for example, when p.v.c. is heated during processing it may decompose slightly and release hydrochloric acid which will attack mild steel equipment. Again, acetate contents of over 55% in cellulose acetate lead to trouble with copper. Plasticiser also sometimes leaches out of p.v.c. and can cause discoloration of cloths or degradation of electrical properties of insulation.

optical properties

As the materials we are considering are mostly either transparent or pale coloured in the pure state, suitable pigmenting and filling produces a range from extreme clarity (absorption less than 0.5% in the visible spectrum) to absolute opacity. There is some limitation of colour due to the milky or yellow

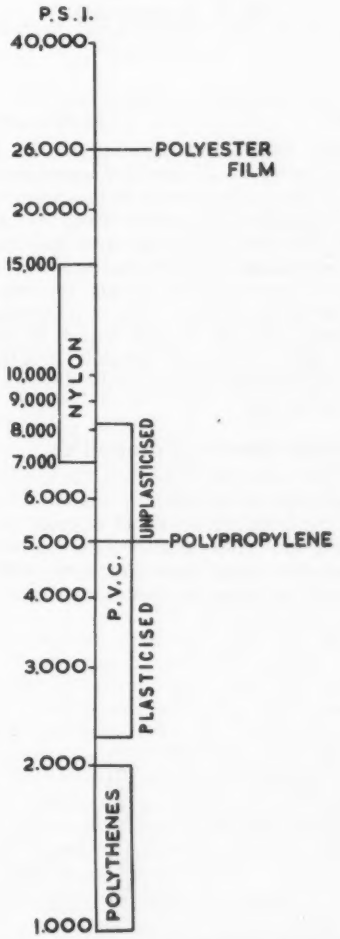


Fig. 3. Tensile strengths

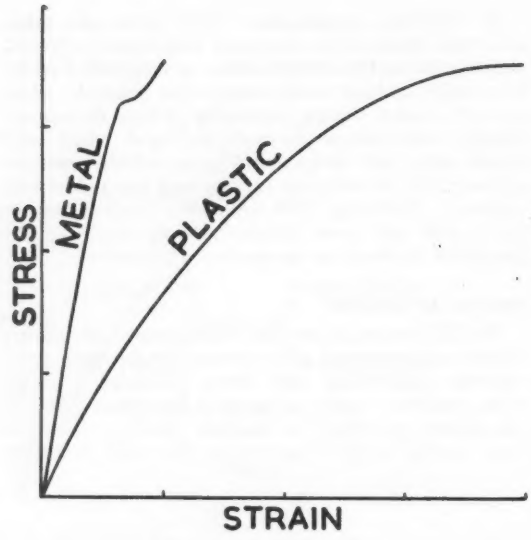


Fig. 4. Tensile test.

tinge of most plastics, but this is not very important in practice.

Refractive indices vary and for acrylics are much lower than for glass. If used for lenses therefore the curvature of the surfaces must be much greater, which may be unsightly or otherwise inconvenient. Nevertheless, acrylic elements can be used with polystyrene to make achromatic doublets in a manner similar to the use of Crown & Flint glasses for this purpose. Another useful possibility is that of piping light along a transparent rod. If the rod wall is hit at a small angle the light is reflected internally, and in this way otherwise inaccessible places can be illuminated using a suitably bent rod.

physical and chemical properties

Engineering may be defined as the exploitation of the properties of materials, and "Strength of Materials" is certainly a subject of great importance to the engineer. Here plastics show up very well as tensile strengths range from just over 1,000 p.s.i. to 100,000 p.s.i. or more in special circumstances (Fig. 3). The two extremes represent respectively low molecular weight polythene and polyester film. Nevertheless, the behaviour of a plastic under test is not the same as that of a metal.

The stress/strain curve of a metal is more or less constant and is a useful design tool from which performance of parts can be calculated. This does not apply to plastics and Fig. 4 shows typical results for a metal and a plastic. A glance at the diagram will reveal that whilst the slope (modulus) for the metal is steady up to the yield point, the slope for the plastic varies with the strain. The two substances have the same ultimate tensile strength, but the metal breaks at relatively low extensions whilst the plastic stretches a long way before it fails.

Varying the conditions under which a metal is tested has little effect on the result but both temperature and straining rate alter considerably the figures obtained with a plastic. At low temperatures tensile strength is greater than at room temperature and the plastic is stiffer and more brittle. On the other hand, if it is heated tensile strength decreases, and greater flexibility and "rubbery" properties are observed. Again, alteration of the straining rate produces a modified curve, the material under test appearing stiffer and stronger with a high than with a low rate.

If a test piece is loaded the initial elongation will be rapid but as time goes on the strain will rise more and more slowly until, at the end of a considerable interval, there will be very little more increase. On removing the load the opposite happens. First the sample contracts quickly, and then moves gradually to very near its original size. The final reversion is then extremely slow and some plastics show permanent set (Fig. 5). Fig. 6 shows the combined effect of heat and straining rate on the stress/strain curve.

At first sight the tensile strengths of plastics may not appear very impressive when compared with those of metals, but it must be remembered that for many engineering applications the ratio of strength to weight is more important than the actual strength. The specific gravity of plastics is generally between 0.9 and 2.5, whereas that of aluminium, the lightest common metal, is 2.5 and that of steel nearly 8. This means that the specific strengths of plastics equal or exceed those of metals, except sometimes aluminium. It is not irrelevant to note here that the low specific gravity of plastics means that their cost per unit

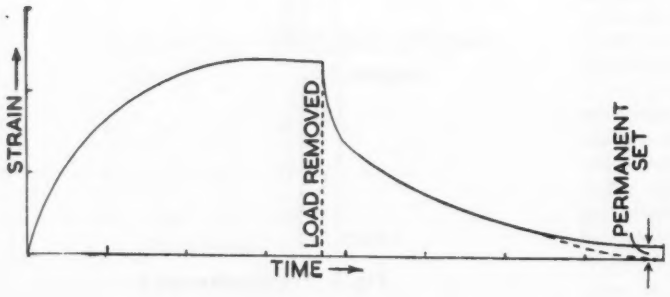


Fig. 5. Creep

volume is therefore low, and although a consideration of the price per pound sometimes appears to rule out a plastics material for a given job, a comparison of volume cost may well show that the use of a plastic can give a saving—except perhaps when the part in question is at present made from mild steel, wood or paper.

The surface hardness of plastics (which can be measured in a similar way to that of metal) is low—but it must be remembered that some plastics are rubbery. B.S. softness is usually quoted but this must not be confused with the softening point, discussed later. Curiously enough soft plastics have often remarkably good abrasion resistance, nylon being the best choice in this respect. Good results have also been achieved with plasticised p.v.c. of B.S. softness of about 6.

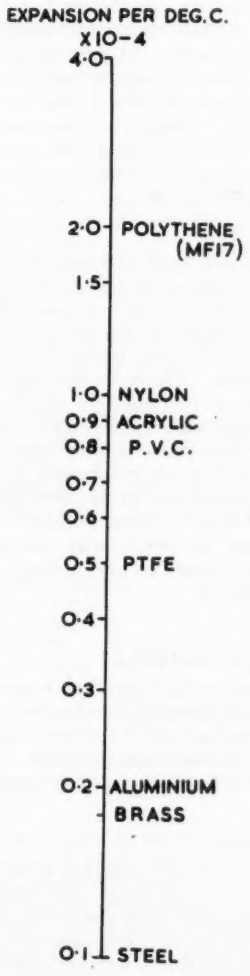


Fig. 7. Coefficients of expansion

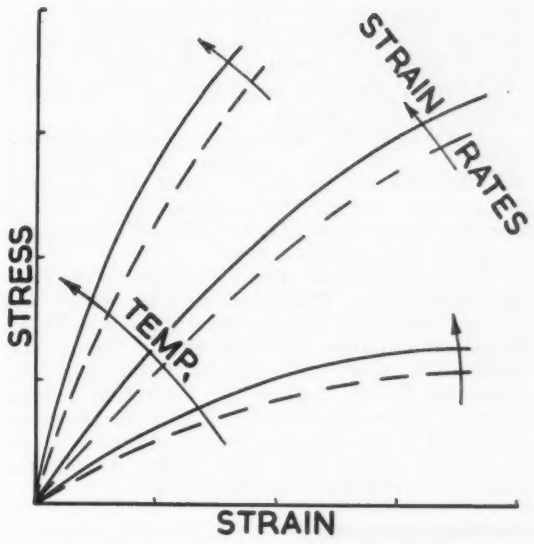


Fig. 6. Effect of temperature and strain rates on tensile test.

thermal properties

Coefficients of expansion are much higher than those of metals and are compared in Fig. 7. This must be borne in mind when designing a system using both plastic and metal, and in such things as pipe line supports and joints. It also means that if in use there are temperature variations, then tolerances cannot be very close with plastics.

As stated earlier, plastics become soft at mildly elevated temperatures and a figure of 60° or 70°C. must generally be regarded as a working limit. However, there are exceptions to this. For example, nylon and polypropylene can both be sterilised at temperatures above 100°C., and p.t.f.e. is outstanding amongst plastics as it can be used safely at up to 250°C.

Because of their molecular structure plastics do not have a precise melting point, although for some materials a melting point is sometimes quoted. This is in fact the temperature at which the last small crystallites in the material disappear. Because the material will have softened before this temperature is reached, the melting point is of little use for design purposes. A more useful criterion for the designer is the "softening point" measured in a defined manner. Many different softening point tests have been devised, but essentially all consist of loading a sample in a specified way and then raising its temperature. The softening point is defined as the temperature at which an arbitrary amount of strain exists and—from what has been said about tensile tests—it will be realised that the rate of heating will affect the apparent softening point.

If a thermoplastic is heated, strained and then cooled whilst retained in its new position, it will become fixed in that conformation. But the strain is locked in and on reheating the specimen will revert

to its original shape. This strain memory is an attribute of which much use is made in the manipulation of plastics, for instance in sheathing. On the other hand it can prove a drawback where stretched sections shrink on heating.

To complete the information about mechanical effects of temperature variation, low temperature measurements are necessary. Cold flex and cold shatter tests measure the temperature at which a specimen breaks when strained a measured amount in a specified way, usually in bend.

The final important thermal property is the thermal conductivity. Plastics all have low values and are good insulators, either in sheet form or as foams. Applications range from refrigerator lining and insulation to cavity wall insulation in buildings. An interesting fact is that the air content of a foam increases the insulation only up to a certain point. After that it appears that convection currents in the air bubbles transfer heat more quickly than do the solid material or the moderately foamed.

electrical properties

Electrical engineers recognised very early the valuable properties of plastics as electrical insulants. This realisation came naturally from the search for synthetic shellac to impregnate paper and cloth, used for insulation even today. Of course, factors other than the electrical resistance of a material govern its choice for a job, but here attention will be concentrated on plastics as insulators. First of all, apart from intrinsic qualities, homogeneity of structure is desirable, particularly when fillers of one sort or another are used.

There are two distinct sets of insulating circumstances to be taken into account. If direct currents only are of concern, volume and surface resistivity, dielectric strength and susceptibility to tracking are the properties to be considered. If insulation at radio frequencies is required, then dielectric constant and power factor must also be reviewed.

Volume resistivity figures quoted for plastics vary between 10^8 and greater than 10^{19} ohm cm., but the value of these published figures for design purposes is questionable, as in practice surface dirt and ambient humidity may cause a considerable drop in the apparent volume resistivity. Determination of volume resistivity for, say, polythene (10^{19} ohm cm.) is in any event very difficult and means that currents to the order of millionths of micro-amps have to be measured. Nonetheless, more significant results can be obtained from power loss test. These remarks also apply to the determination of surface resistivity.

More useful is an idea of the voltages at which insulation is broken down. In practice, breakdown voltages range from 200-4,000 volts per 0.001 in., although of course other factors have to be considered to determine the real usefulness of a given material for a given purpose—for example, mechanical failure of a film on creasing will render it useless for electrical insulation, however good the breakdown voltage of the uncreased material.

Tracking is the phenomenon exhibited by some insulating materials whereby an arc causes chemical breakdown of the surface of the insulator to form a conducting path. Of plastics, the only group with a tendency to fail due to this cause are the phenolic resins and moulding powders, but the actual mechanism is not yet completely understood.

Turning now to r.f. requirements, it is well known that the discovery of polythene meant that radar could be developed and, at a later stage, a trans-Atlantic telephone cable became a possibility. The dielectric constant of a material depends on the polarisation and on the polarisability of its molecules, and the charging current of a condenser may be regarded as orienting the molecules of the dielectric and thus storing energy in the dielectric which is released when the molecules are allowed to return to their unoriented positions.

When alternating currents are applied to condensers, the molecules first move one way and then the other under the influence of the reversing electric field. Work has to be done to overcome their inertia and the forces between them, and this is dissipated as heat. Materials with low power factor oppose these reversals only slightly, but as frequency increases so naturally do the losses. At some point the molecules resonate with the alternating current and here the maximum loss is experienced, the loss subsequently dropping despite increase of frequency. Polythene however not only has a very low power factor, but exhibits a linear variation of power factor with frequency up to 10^9 c.c./sec.

materials

Having reviewed briefly factors affecting the choice of plastics for particular duties, some of the more common materials can be examined in some detail. So many exist that it would be impossible to survey them all, or even to attempt to list the theoretically possible variables. There is no need to be precise about methods of manufacture which involve problems of chemistry and engineering of differing magnitude, but an indication of the origin or process of manufacture will be given where it is of interest. It is logical and convenient to divide this survey into the classes defined in the section on nature and structure of plastics, and to begin with the thermoplastics which are more numerous and perhaps more versatile than the thermosets.

thermoplastics

(a) CELLULOSE PLASTICS

In this group come the first man-made plastics. They are not produced by synthesis of monomers, but rather by modification of natural cellulose in the form of, for instance, cotton linters or wood pulp. Sometimes therefore they are referred to as semi-synthetics.

(i) nitrocellulose

This is produced by processing cellulose with nitric acid but despite being tough and abrasion resistant, and having good electrical properties, it is little used in industry because of its inflammability. Denitrification or various additives can be used to control the inflammability and moulding powders are available, besides cast sheets and rods.

"Parkesine" was patented in 1865 but commercial development in this country was forestalled by that in the U.S.A. under the name "Celluloid". It can be plasticised with camphor or chlorinated solvents, for injection moulding. Apart from its use in dopes and lacquers and leathercloth, the main outlets are explosives, toys and photographic films.

(ii) cellulose acetate

If acetic acid is used instead of nitric acid the much less inflammable cellulose acetate is produced. Surprisingly therefore technical development was slow and, although patented in 1894 it was not available in any quantity until 1901. After the First World War, plant which had produced protective lacquers for aircraft was converted to make acetate rayon, still the largest use of the material. Nowadays, film, sheet, rod and tube, besides moulding powders and extrusion compounds, are made, for which the main applications are packaging and safety photographic film. Tool handles and electrical goods are other typical products.

(iii) cellulose acetate butyrate and ethyl cellulose

Neither of these materials is produced in the U.K. but both are quite important in the U.S.A. They have similar properties to cellulose acetate but show improvements in some respects. For instance, the water absorption of c.a.b. is very low and the s.g. of ethyl cellulose is the lowest of those of the cellulosics. Another advantage is that ethyl cellulose needs only very small proportions of plasticiser and can therefore be considered where materials must be non-toxic. Car accessories, pipes for water, gas and oil and machinery housings and tool handles are typical jobs done by c.a.b., whereas ethyl cellulose is used for steering wheels, cable insulation and telephone parts.

(b) VINYL PLASTICS

Chemically this class is characterised by the presence of a group of the form $(CH_2—CH.R)$. It includes polythene, p.v.c. and polystyrene, besides other less important plastics. This survey is limited to the three mentioned, and polypropylene.

(i) polythene

The simplest material of the series, chemically $(CH_2—CH_2)_n$ There are two processes for polymerising ethylene, one involving high pressures (I.C.I.) and the other low pressures and special catalysts (Ziegler). The material made by the Ziegler process has properties different in degree from those of the material made by the high pressure process. In general it produces materials of higher density, higher softening point, greater tensile strength and greater stiffness.

The number of units in the molecular chain can be varied in polymerisation and hence the molecular weight characterises polymers. As suggested earlier the higher molecular weight materials are stronger and more chemically resistant. Electrical and most thermal properties are not affected by molecular weight but softening point is. High molecular weight also means that low temperature flexibility is good.

A figure proportional to molecular weight is given by the viscosity of the particular molten polythene and melt flow index is an arbitrary measure of it (the amount in grammes of polythene extruded through a standard jet by a standard force in ten minutes at 190°C.). This grade number is inversely proportional to viscosity and gives, besides an indication of molecular weight and properties, a guide to processability.

In general mechanical strength is low (between 1,000 and 2,000 p.s.i.) but can be increased by cold drawing because of the partly crystalline nature of polythene. Electrical properties are excellent and polythene is unaffected by most chemicals. As it is easy to mould, low in specific gravity (and therefore cheap) it is simple to see why it is so widely used for insulation of cable and wire, in television and radar, for toys, houseware and laboratory goods. Film is made for packaging, horticultural and building applications, and containers of every sort are becoming more and more common. Slip agents, anti-oxidants and pigments are added to the various different polymers, to make compounds of this versatile plastic, for particular jobs. Its main disadvantage is that its low softening point means it is difficult to sterilise. It also, particularly in high melt flow index easily moulded compounds, suffers from a phenomenon known as environmental stress cracking. Polar organic liquids like alcohols and ketones cause polythene to fail suddenly if it is stressed in contact with them. The mechanism is not really understood, but low melt flow index polymers and compounds are immune as are unstressed articles.

(ii) polypropylene

A new thermoplastic with the chemical structure $(CH_2—CH.CH_3)_n$ produced by a polymerisation method due to Ziegler & Natta. Atactic polypropylene, in which the $–CH_3$ groups are randomly oriented around the main chain, is amorphous but the isotactic structure, which has a regular disposition of the $–CH_3$ groups, is a plastic with many attractive properties.

The remarks about molecular weight and m.f.i. of polythene apply here. Remarkable mechanical properties are exhibited at elevated temperatures and these are directly attributable to the high m.p. Tensile strength is of the order of 5,000 p.s.i., and at 100°C. it is about 1,000 p.s.i. or equivalent to that of a polythene of density .925 at room temperature. The specific gravity of polypropylene is the lowest of any thermoplastic, 0.9 – 0.91, and this means that the material is potentially cheap on volume basis.

Use in the U.K. is not, so far, very high, but applications such as hospital equipment, where sterilisation is essential, and other jobs where heat resistance is necessary, point naturally to polypropylene. It may be possible to modify compounds for use in hot water plumbing and short term installations are already being considered. Mouldings can be made with short cycling times and mould shrinkage is almost equal in machine and transverse directions. Thus difficult mouldings can be made with no danger of distortion such as could occur with high density

polythene. Finally, polypropylene is rigid, has good impact strength and does not suffer from environmental stress cracking.

(iii) polyvinyl chloride

Vinyl chloride (CH_2=CH.Cl) can be polymerised in several ways to form p.v.c. but only the emulsion and granular processes are employed in this country. In the former, an emulsifying agent is used and the resultant polymer is bound to contain it and any residual catalyst. Therefore emulsion polymer is not pure and its electrical properties are adversely affected, but by virtue of their particle form emulsion polymers are easily processed.

The molecular weight of a vinyl chloride polymer is referred to by a "K" number, proportional to it and usually between about 30 and 65. Good mechanical properties are again associated with high K values, and higher processing temperatures are needed. P.v.c. softens at about 160°C. but unfortunately it decomposes easily at very little higher. Some decomposition indeed occurs even below 160°C., and this means that polymers cannot be used alone to any extent and have to be compounded with, at least, a heat stabiliser.

The polymers have excellent resistance to inorganic chemicals and are little affected by most organic chemicals. They have good mechanical strength and, because they liberate chlorine on burning, are self-extinguishing. All these properties may be modified in compounding and it is more difficult to generalise about p.v.c. than about most other plastics. Even the appearance may vary from soft and rubbery to hard and rigid. The specific gravity also varies considerably, but is around 1.3.

After the polymer the most important ingredient of a p.v.c. compound is the stabiliser. Lead salts are commonly used but complex systems are developed for special compounds such as those demanding non-toxicity. The function of the stabiliser is to limit the decomposition which can occur during the processing which leads to discoloration and degraded properties.

Plasticisation is a very powerful technique by which the flexibility and softness of a compound may be widely adjusted. The most usual choices of plasticiser are poor solvents for the p.v.c., high boiling point organic liquids such as di-octyl phthalate, di-butyl phthalate, tri-cresyl phosphate, etc. The choice is governed by toxicity and inflammability considerations besides softness and cost, and cheaper secondary plasticisers may be used. These are less compatible with p.v.c. and can only be used in conjunction with primary plasticisers. Extenders are not miscible with p.v.c. on their own but can be used to substitute for some part of the expensive plasticiser content of a compound, with little effect on its properties. Chlorinated paraffins and paraffin waxes and oil extracts are good examples of this class of additive.

Fillers are often used to cheapen compounds, perhaps floor tiling compounds being the best example, although wearing properties may be bettered as well. Certain electrical clays added to insulation grades increase the v.r. achieved. Mineral fillers are usually used but as they are relatively dense saving in cost may not be as great as expected and, of course, mechanical properties and surface finish have usually to be sacrificed.

Colouring can be controlled by the addition of pigments. Crystal clear compounds can be made; these usually have to be only lightly stabilised due to the pigmenting effect of stabilisers. Lubricants are also sometimes used to make easier processing compounds.

Compounds vary from pastes which contain large quantities of plasticiser, to flexible compounds like rubber and to hard rigid grades consisting of little but high K value polymer and stabiliser. Uses for such a wide range of related products include conveyor belting, rainwear, tube and fittings for chemical plant, hose pipe and, of course, cable and wire insulation and sheathing.

Copolymers or heteropolymers of v.c. and vinyl acetate should now be mentioned. During polymerisation the second monomer is added in the desired proportion, between 5 and 40%. An advantage of compounds based on copolymers is ease of processing, the processing temperature for a given K value being lower than that for a homopolymer. However, copolymers do lose chemical resistance and are more inflammable than homopolymers. The most important applications for copolymers are compounds for flooring, for gramophone records and for making solutions for coatings.

(iv) polystryene

A very important material because of its cheapness, low s.g. (1.06) and ease of moulding. Its principal defect is brittleness but high impact grades have been developed. The monomer is (CH_2 = CH. C_6 H_5), prepared from ethyl benzene. The material is transparent, with a high refractive index, and when struck emits a metallic sound. Colouring possibilities are very good, but appearance never quite equals that of the acrylics.

Mechanical strength is high but on exposure polystyrene crazes and yellows with age. Its chemical resistance is good to acids, alcohols and alkalis and it is outstanding electrically. Unfortunately its use is ruled out for many applications by its rigidity and brittleness. It is used in radios, refrigerators, lighting fittings and toys.

(c) ACRYLICS

These materials are made from acrylic acid, CH_2 = CH.COOH and its derivatives, which are easily polymerised. The three most important are the polymers of methyl methacrylate and methyl and ethyl acrylate. The acrylates are used mainly in the textile and leather industries and the most important of the acrylic plastics is

(i) polymethyl methacrylate

This material is another transparent one, chemically $(CH_2—C.CH_3\ COOCH_3)_n$. It is available either as sheet cast from monomer or as moulding powder, the main difference being the number of monomer units in the chain molecule; 500-600 are usual for the moulding powder and 1,800-3,000 for the cast product. The material is uniquely clear and stable and

passes 92% of visible light (more than glass). Ultra violet and infra red transmission is also superior to that of glass. Specific gravity is 1.16 which compares favourably with glass at 2.5, where weight is important (as in aircraft canopies).

Tensile strength is high and so is impact strength. As far as d.c. is concerned, electrical properties are good but polymethyl methacrylate cannot be compared with polythene or polystyrene at high frequencies.

Chemical resistance is good for dilute acids, concentrated acids and aliphatic hydrocarbons, but it is attacked by chlorinated hydrocarbons, aromatic hydrocarbons, ketones and esters. Weathering properties are excellent and it is easy to work. An attractive colour range is available and another useful property is that of "piping" light by internal reflections in a rod. Shaping techniques are used extensively to make lighting fittings, sinks, drainers and baths, and advertising signs. Television implosion guards are made by shaping from sheet and also by moulding from powder, while reflectors and rear light covers for cars are made by moulding.

(d) POLYAMIDES

(i) nylon

The name nylon covers a range of materials of similar chemical constitution, but differing widely in their detailed properties from one another. They are identified by numerals denoting either the number of carbon atoms in the diamine and the di-acid from which they are made—e.g., 66, 610—or if they are made from an amino-acid, the number of carbon atoms in it—e.g., 6, 11. Copolymers can be made and plasticisation is also employed. Finally, by substituting one of the hydrogen atoms in the amino groups in the molecule of the nylon, polymers soluble in alcohol can be produced.

Very good mechanical properties are typical of the range of nylons and another great advantage is their relatively high softening point, which means that mouldings can be sterilised. Unfortunately nylon absorbs up to 2% of water in 2 hours with consequent dimensional change. The equilibrium water content varies with relative humidity and rises to almost 8% for a type 66 polymer at 100% r.h. Toughness and abrasion resistance are two more desirable properties, nylons being outstanding for the latter. In fact, nylon gears have been known to outlast metal gears with which they mesh. Specific gravity is about 1.1 and cost tends to be rather high, thus ruling out consideration of this material except for special duty applications.

The electrical insulation values are reasonably good at low humidities and temperature but deteriorate rapidly with increase of humidity and temperature. Toughness and temperature resistance demands often lead to the use of nylon, and abrasion resistant sheathing is usually made from it.

Resistance to organic media is good; petrol, carbon tetrachloride, benzene and xylene have little effect. On the other hand, attack by concentrated acid is quite rapid. Alkalis have little effect even at concentrations of 20%.

A peculiarity of the nylons is the sharp melting point they exhibit between 200°C. and 280°C. They do not soften gradually, as do most other plastics, and so techniques have to be modified specially to process them. Typical uses, apart from as a textile or monofilament, are pressure tubing, gear wheels, non-lube bearings which operate up to 500 p.s.i., and sterilisable mouldings.

(e) FLUORINE PLASTICS

(i) polytetrafluoroethylene

P.t.f.e. is a truly remarkable material. It is assumed to have the structure $(CF_2—CF_2)_n$ and its resemblance to polythene will be obvious. The bond between the carbon and fluorine atoms is one of the strongest known and the only substances attacking p.t.f.e. are fluorine compounds at elevated temperatures and molten alkaline metals. Thus severe chemical handling problems can often be solved by the use of p.t.f.e. particularly as it has a working range up to + 250°C. for continuous use and up to 300°C. for non-continuous use, while it remains flexible at temperatures of – 183°C. (liquid nitrogen) and below.

As a dielectric p.t.f.e. is better than polythene and it is indeed the best solid dielectric known. Permittivity and power factor are low and do not vary with frequency or temperature. Tracking resistance is good, and as it is neither wetted by nor does it absorb water, its merits can clearly be seen.

The coefficient of friction is very low, and often quoted is "equivalent to wet ice on wet ice." Thus p.t.f.e. provides a useful bearing material and also a non-stick surface. A disadvantage for this type of application is that resistance to abrasion is not very high. Allied to low friction are the non-sticking properties, so that p.t.f.e. can be used in flax handling machinery, packaging equipment where glues cause trouble, and even on the runners of transAntarctic sledges.

Creep and cold flow limit the unsupported use of p.t.f.e. as a bearing material, but when used in conjunction with asbestos, wool or phosphor-bronze shells, its scope can be greatly extended. Although it is itself harmless, decomposition of p.t.f.e. releases toxic substances, hence care must be taken in high temperature applications. The final disadvantage that must be mentioned is cost. The price of the raw material is high and so is the s.g. of 2.2.

P.t.f.e. is suited very well for almost all applications of plastics materials, but its cost is high and so it is used in practice only where nothing else will do. Examples that spring to mind are fuel pipe linings in rockets and aeroplanes, gaskets in chemical plant and some critical electronic mouldings. P.t.f.e. covered wire is used in corrosive environments, and its non-stick properties are exploited in dough rollers.

A final point is that p.t.f.e. needs special techniques to manipulate it as it behaves neither as a thermoplastic nor a thermoset.

(ii) polymonochlorotrifluoroethylene (p.c.t.f.e.)

$(CF_2—CF.Cl)_n$ is the chemical formula for this product which in many ways resembles p.t.f.e. It

will be seen that a fluorine atom is replaced by chlorine, hence an analogy can be made between polythene/p.v.c. and p.t.f.e./p.c.t.f.e. The effect of the substitution is to increase the tensile strength and reduce creep or cold flow, but the dielectric properties are much inferior, although d.c. insulation is similar to that of p.t.f.e.

An advantage is that this material can be handled by conventional extrusion and moulding equipment. Against this is the price, rather higher than that of p.t.f.e. It is used for similar work to p.t.f.e. except h.f. insulation and chemical plant where halogens and aromatics are present, as some attack p.c.t.f.e. although it is otherwise nearly as inert as p.t.f.e. Another limitation is in working temperature, which is rather lower than that of p.t.f.e. although better than those of most thermoplastics, being about 200°C.

(f) POLYESTERS

(i) polyethylene terephthalate

Most of the polyester group of plastics are thermosetting resins and are dealt with in the next section, but polyethylene terephthalate film is a thermoplastic and melts sharply at 265°C.—thus resembling nylon. It is only available in film form or as "Terylene", and is made by a melt extrusion process involving biaxial stressing to develop its good mechanical properties. Film thicknesses from 0.00025 in. to 0.004 in. are available in the U.K. and up to 0.015 in. in America.

Two grades of film are available, one which has outstanding clarity but which is difficult to handle as it will not slide freely over itself, and the other very slightly hazy (but clearer than the best polythene film). Its s.g. is 1.38 and it is quite expensive, compared with polythene film. Nevertheless, due to its high tensile strength, yield per lb. of equivalent tensile strength film is about seven times that of polythene.

The film is an excellent electrical insulator, its dielectric strength of 4,000 volts per 0.001 in. being outstanding. V.R. at 10^{19} ohm cm is also very good and thus polyester film is used laminated to pressboard for slot liners in electric motors. Metal deposited on the film simplifies the manufacture of capacitors and also makes for considerable saving in size. Other decorative and protective applications take advantage of its resistance to water and water vapour and its generally good chemical resistance. It can be used at up to 150°C.

thermosetting plastics

These materials are made in enormous quantities but the importance of the moulding powders is perhaps decreasing. Large numbers of electrical accessories, toilet seats, distributor caps and other car parts are made from phenolics besides vacuum cleaner components, thermos jugs and radio cabinets. The resins used for making blockboard and veneers are still very important as are the various resins used for fibreglass laminates.

(i) phenolic resins and powders

The resins are dark in colour so the colours of products using them are very limited, generally black or brown. They are heat curing and have good moisture resistence, are strong but suffer from low cracking resistance. Phenolic resins are used for laminating weatherproof plywood and for making synthetic resin bonded papers. In the foundry, resins find applications for core bonding and shell moulding, and abrasive wheels are often bonded with them. Temperatures of around 150°C. are needed for the cure.

Moulding powders are made by using various fillers with the resins and so the properties of the powder can be modified. Processing requirements are indicated by the flow, stiff, medium and free being available from manufacturers. Stiff flow powders give better surface finish and less shrinkage, but obviously deep articles have to be made from free flowing powders. Cure time is also important commercially, and although cheaper powders can be made by using cresol in place of phenol, such a substitution increases cure time.

Returning to fillers, wood flour is commonly used but for special heat resistant grades asbestos can be used. Powdered mica gives good dimensional stability and diced fabric can be incorporated for good shock resistance.

(ii) amino resins and moulding powders

Very similar to the phenolics but curing more quickly and at lower temperatures, the aminos also have the great advantage of being naturally light coloured and therefore they can be coloured. They are less water resistant, weaker and have worse electrical properties than the phenolics, except in tracking.

Sub-divisions of this type include urea, thiourea and melamine, the latter having greater surface hardness than the others. The resins are used for veneers and chipboard, etc., where colour is important, and mouldings such as light switches, beakers, vacuum jugs and buttons.

(iii) polyester resins

The most important application of these resins is the manufacture of fibreglass laminates. Other fillers can be used and curing processes may be of three types: heat alone (about 150°C.), heat and catalyst (40°C.—120°C.), or low temperature cure with special catalysts. Time taken for cure ranges from several minutes to several hours. The type of filler and proportion of resin to filler decides the actual properties of the finished laminate, but in general the strength-to-weight ratio is high, although they are not very stiff. This is, in fact, the main drawback from the structural point of view. Stiffness-to-weight ratio in tension is much less than that of metals, but in bend is very much greater.

Resistance to water and organic solvents is good and to fairly highly concentrated acids and alkalis. The electrical properties are fairly good and the resins are used for potting, besides the more familiar car and boat bodies.

(iv) epoxy resins

Epoxy resins can be used to give chemically resistant and mechanically strong products, and the uses vary from cold or stoving curing lacquers through cements to conventional laminations for structures with high strength to weight ratios. The price tends

to be high and electrical properties at high frequencies are not as good as those of the polyesters. Nevertheless, potting gives strong, moisture-proof units with high dielectric strengths. Another interesting use is for drop hammer tools where life obtained is greater than with the conventional metal ones.

working with plastics

Wrought forms of plastic can be worked very simply, using woodworking tools and methods. Edges must be kept sharp, but the lack of grain means that there are no external limitations of material placed on the craftsman. Several plastics can be cemented and others can be welded using a hot air torch and a plastic filler rod. These, however, are not the important ways of fabricating plastics. The moulding and fabricating methods used for working the bulk of the plastics are described below.

In general, machinery to manipulate plastics is large and has to be heavily and precisely built. This means it is expensive and so it has to be in use continuously to pay for its keep. Nevertheless for mass production of complicated or simple articles the plastics industry is ideal.

mixing and compounding

The primary function of mixers is to disperse perfectly the ingredients of, say, a p.v.c. compound. Sometimes heat is needed but at other times mixing is done cold. Paddle-type mixers generating large shear forces are used to prepare p.v.c. pastes. Simple pre-mixers of the ribbon type are used with the various components of p.v.c. compounds. They are then transferred to an open mill, which consists of two rollers, one rotating faster than the other. Here the mixing is completed and the compound can be taken off the mill (Fig. 8) as a crepe ready for feeding to a chipper, or direct to a calender or extruder. This method is only really suitable for small production and an internal mixer is much more efficient.

With an internal mixer the premix is fed to it in specified quantities. In the mixer, heat and pressure are applied and the temperature is allowed to rise to 130° or 150°C. The material is then "dropped" and transferred to the open mill for further mastication and sheeting before cooling and chipping.

Extruders (q.v.) can also be used for mixing intimately pigment and other additives with nylon, polythene, etc. The mixture must be first tumble blended and then fed to the extruder. It is extruded as a tape or rod and allowed to harden before being chipped again.

compresion moulding

This is the simplest method of moulding and essentially consists of placing a weighed amount of moulding powder into one half of a heated mould and closing the other half on to it. Pressure of the order of two or three tons per square inch is applied and this causes the plastic to flow and fill the mould cavities. Any excess appears as "flash" at the split line of the mould.

With intricate mouldings the powder is distributed in the different parts of the mould to facilitate flow. Alternatively and giving more control, preformed

Fig. 8. Sheeting a compound from a mill. (I.C.I, Ltd., and M. Broomfield, Ltd.)

pellets can be used as they are easier to handle than powder and make the whole process even simpler.

The press has one fixed and one moving platen, usually hydraulically operated, to which the mould parts are fastened. They can be heated by steam, electricity, gas or oil.

A similar process, called transfer moulding, is used when the finished article requires metallic inserts or has internal holes and delicate shapes. Here a small quantity of powder is heated in a "pot" outside the mould and by pressure made to flow through passages to the closed mould.

The main advantage of this technique is that very thick mouldings can be made.

Compression moulding can be used with either thermosetting or thermoplastic materials, but is much more suited to the former. Almost immediately the mould is full it can be opened, as the heat and pressure have converted the discrete particles of powder into what is virtually one large molecule with its strength fully developed. On the other hand, with the thermoplastic the mould would have to be cooled considerably before the article had sufficient strength to be removed. Thus a different process is generally used :

injection moulding

Engineers will be familiar with the technique of die casting, and pressure die casting is analogous to injection moulding. The moulding powder is fed from a

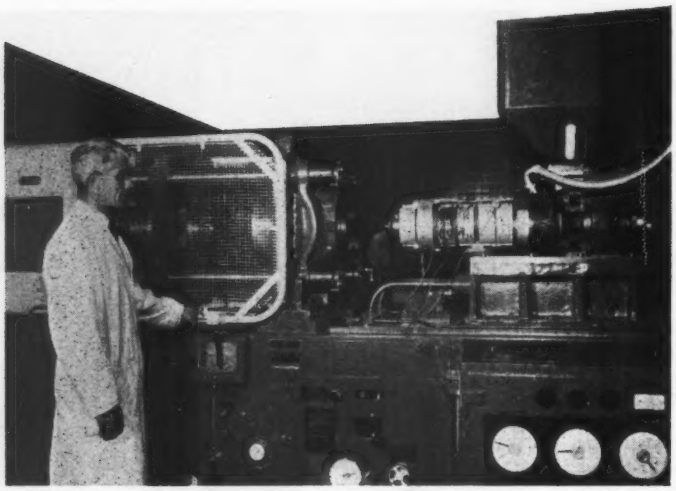


Fig. 9. Injection moulding machine (I.C.I. Ltd)

hopper into a heated cylinder, where it forms a reservoir of molten material. Pressure from a piston or ram then forces plastic through a nozzle into a closed mould, where it solidifies. Finally the mould automatically opens and the moulding is ejected (Fig. 9).

Electric heating is usually employed and a spreader is incorporated in the cylinder because, due to the generally low thermal conductivity of plastics, it is desirable for heat to be applied to only a thin layer for uniformity. Sometimes the piston is replaced by one or more screws and these perform so much mechanical work on the material that they contribute greatly to heating it, and it is then possible to mould some of the more difficult moulding materials such as rigid p.v.c.

The capacity of injection moulding machines is measured in weight, e.g., so many ounces, and the usual material referred to is polystyrene. It has a specific gravity of 1.06, hence when considering polythene of s.g. 0.92 a 6 oz. machine will produce a moulding weighing $6 \times 0.92 \div 1.06 = 5.2$ oz. For this reason cubic capacity is sometimes quoted instead. Machines vary from $\frac{1}{4}$ oz. to 360 oz. capacity, the latter able to mould refrigerator linings, dustbins, etc., at one shot.

Injection machinery cannot be used for thermosetting products because any attempt to do so would result in the cylinder becoming filled with immovable, fully cured, material. Difficulties also arise with nylon, which exhibits a sudden melting point rather than the softening range of other thermoplastics. Special designs of nozzle are needed to prevent dripping, and another problem is that higher temperatures are required demanding special heaters. The development of large injection machines is perhaps the most significant recent improvement in plastics processing machinery.

extrusion

The demand for plastic-covered wire, car trim and upholstery edging, tubes and many other sections, both rigid and flexible, is met by extrusion. Machines are superficially similar to injection moulding apparatus but their barrels contain one or more screws working at small clearance with the wall. The barrel is heated, but as extrusion proceeds the friction of the screw provides so much heat that often the external supply can be cut off; sometimes even cooling devices have to be incorporated. If the screw is cored and can be cooled this increases the friction and thus raises the temperature. It provides a good way of increasing the work done on the plastic.

As the section emerges from the die it starts to cool in air or it may be passed through a water bath to accelerate the effect. In either case a haul-off has to be provided, typical examples being drums on to which wire and flexible sections are wound, simple conveyors, or twin caterpillar haul-offs which can handle almost any section due to their resilent pads. (Fig. 10.)

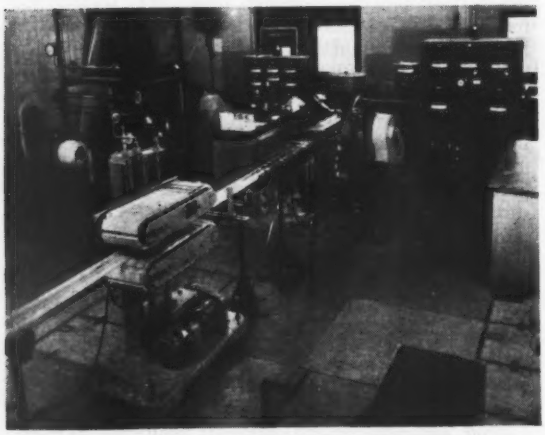


Fig. 10. Extrusion of acrylic section (I.C.I. Ltd)

A useful auxiliary technique is that of post-forming. If, for instance, a tube is slit when still hot as it leaves the die, it can be led over formers to produce a gutter or trough section before it hardens. Hence a simple circular die can be used with relatively cheap formers to produce a range of related shapes.

Extruders can be used to make blown films. Usually a cross-head is used and a thin-walled polythene (or other material) tube is extruded upwards. It is led through nip rollers and inflated by air pressure introduced through the torpedo. The bubble thus formed can be controlled in size by haul-off and extrusion speed as also can the wall thickness. This is an elegant method of producing lay-flat tubular film from any plastic material with a fairly high melt viscosity. The extrusion can equally well be downwards but then the extruder has to be elevated. Horizontal mounting allows the film being produced to sag so that it is difficult to control, and this arrangement is seldom used.

Whilst discussing production of film two other methods must be mentioned, using conventional extruders. In both, film is produced by a long slit die and can then be quenched either by casting in a water bath or on to chilled rollers. The latter is capable of modification for coating paper, board or other flexible substrates. Again the haul-off mechanism needs to be accurately controlled to make an acceptable product.

Two similar special techniques used with two very different materials are of interest. Thermosetting resins can be extruded using special ram extruders in which the barrel is heated in distinct stages. The ram cross section has to be made specially for the extrusion required and it reciprocates in something between 5 and 10 seconds. On the forward stroke powder is pushed into the first heated section, as it comes from the hopper and preheated and compacted at 50°—90°C. The next section is kept at 130°—150°C., so that the powder begins to flow, and the final zone is heated to the curing temperature required and the section sets into its final form.

The processing of p.t.f.e. from a lubricated billet by a constant rate ram extruder has some similarity to the process just described. The extrudate is forced cold from an extrusion chamber through the die, and is then passed through a drying oven where the lubricant is removed. Next the dry extrudate is passed through a sintering oven and the full mechanical strength develops.

There are two processes combining both extrusion and moulding techniques. In one method of extrusion moulding, the Faigle process, an extruder acts as a pump, forcing material through a nozzle into a mould mounted so that it can be pushed away from the extruder, by internal pressure, when it is full. Before this happens another section of mould is clipped on and the process continues until a sufficient quantity is made. The mould assembly can then be split, and the material removed when cooled.

Blow moulding, to produce comparatively large hollow articles such as bottles or jerry-cans, involves extruding a length of tube into a light (and therefore cheap) open mould and then closing it. Air pressure

Fig. 11. Checking thickness of calendered sheet (I.C.I. Ltd)

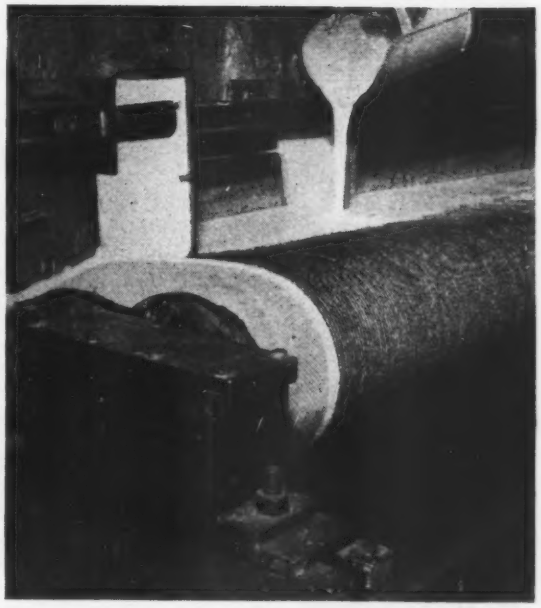


Fig. 12. Spreading p.v.c. by doctor knife (I.C.I. Ltd)

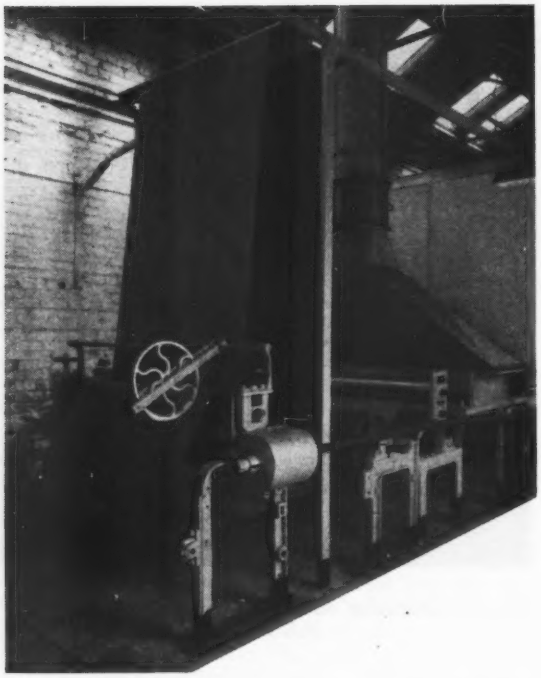


Fig. 13. Curing and hand off for p.v.c. brattice cloth (S. Wales Brattice Cloth & India Co. Ltd. and I.C.I. Ltd)

Fig. 14. Vacuum assisted pressing from acrylic sheet (I.C.I. Ltd)

is used to blow the tube into contact with the mould and on cooling the bottle, etc., is ejected by opening the mould. Automatic equipment is available so that several hundreds of mouldings can be produced per hour.

calendering

Calenders are composed of heated rollers (or bowls) which can be arranged in several different ways, but essentially a "dolly" of plastic is placed between two of the bowls which then press it into a sheet which transfers to the hotter bowl. Subsequent bowls make the sheet thinner until the final film is of a predetermined required thickness. It can then be embossed by a final cold roller, or printed before being rolled up (Fig. 11). Both flexible and rigid sheets can be produced and then laminated in a compression press to produce thick sheet.

spreading, casting and dip coating

When leathercloth, conveyor belting or other coated fabrics are required there are several methods which can be chosen. A doctor knife (Fig. 12) can be used to spread an even thickness of. say, p.v.c. paste over a cloth which is then passed through a heated chamber or under heating lamps to gell it (Fig. 13). A lick roller running in a paste or solution transfers it to the fabric or a hopper might apply the material to fabric carried on a wheel or belt. Then gelation or evaporation of solvent is achieved by heat and the cloth may finally be embossed or printed, as mentioned in the section about calendering.

Dip coating uses the same form of plastic raw materials, i.e., pastes and solutions and in this way plier handles can be covered or electrical components potted. Casting involves filling a mould with p.v.c. paste and gelling it, or a variation known as slush moulding can be used to produce hollow articles. The paste is poured into a hollow mould which is rotated so that it covers the inner surface. Gelling follows and the rubbery lining can be removed easily.

Hot melts can be used for the application of protective coatings; ethyl cellulose is often used or finely divided polythene, nylon or p.v.c. can be applied by a fluidised bed technique. The hot article is immersed in the powder, which is supported by air pressure so that it acts as a fluid. A final variation is the Schori process, used for spraying metals or plastics through a flame gun which melts the particles. They solidify and adhere to the cold surface as they meet the article being coated.

shaping

If a thermoplastic sheet is heated it becomes rubber-like and so can be stretched over a simple former and allowed to cool, when it will be found to have taken up the shape. This gives a simple way of making articles, economic for relatively small numbers, which would rule out injection moulding on tool costs alone. Much ingenuity can be used in the design of shaping methods and such techniques as blowing (by which a near-perfect hemisphere can be produced with simple tools) and vacuum-forming are useful. Male or female moulds can be used in conjunction

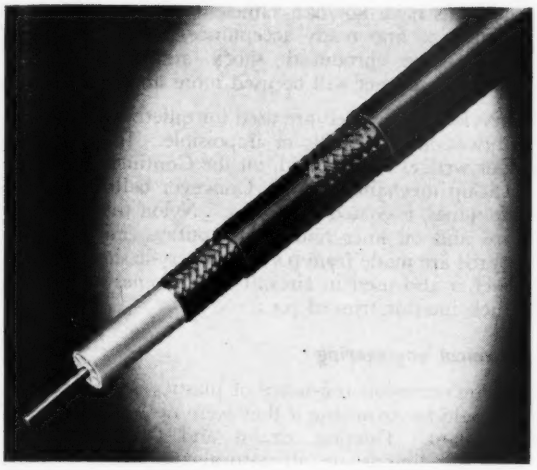


Fig. 15. "Aeraxial" T.V. Relay cable using polythene and p.v.c. This particular construction is protected by British patent 811703. (Aerialite, Ltd)

with rubber pads, and tool and vacuum can be used together (Fig. 14). Items as large as domestic baths can be made by the use of vacuum forming by heating a $\frac{1}{2}$ in. acrylic sheet and drawing into a conventional bath.

using polyester and epoxy resins

There are several methods employed, depending on the result required. Wet lay-up technique is the simplest way of making a laminate, with consecutive coats of resin applied to the reinforcement by brush or spray. When the thickness needed has been built up, the cure is effected either by heat or at room temperature.

A heated mould may be used with a rubber plunger to force the resin into the reinforcement. The pressure forms the fibre and the resin to the required shape, and the cure is completed by the heat.

Dough moulding, used for making press tools, etc., consists of mixing chopped glass fibre, resin and mineral filler to a dough which can be packed into a mould and cured at room temperature and low pressure.

plastics in engineering

So far in this Paper there has been little mention of engineering, but all that has gone before is necessary to understand the reasons for particular choices of plastics in engineering applications. Some jobs can be done almost equally well by more than one of the many synthetic materials available. But a choice must be made and it can only be made by considering the relative importance of factors such as effect of moisture on properties; colour fastness; weather resistance, and so on.

Engineering, too, is an all-embracing term and the intention of giving the following examples is to include some applications in all branches.

electrical engineering

The need for a synthetic resin to impregnate paper for electrical insulation stimulated the chemist and thus had some part in the birth of the plastics industry, and this provides sufficient excuse to look at this branch of engineering first. Thermosetting resins were used early for these applications and when moulding powders were developed, switchgear, terminal blocks, and other electrical accessories were made from them. The lack of resistance to tracking limits the usefulness of p.f. powders, but both phenolics and amino products are very heat stable and resistant. The use of a suitable filler enhances the insulation, and as a final virtue they are cheap.

Cables were produced using p.v.c. and when it became available, polythene. Now combinations of

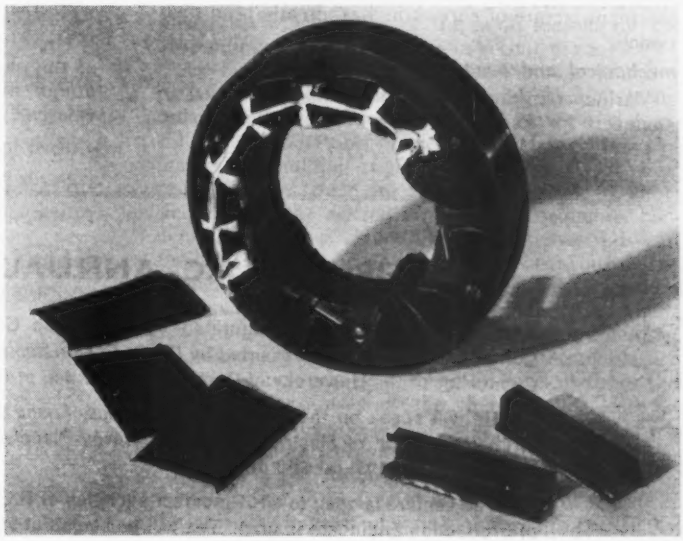


Fig. 16. Polyester film laminate by H. D. Symons, Ltd., as slot liners. (Hoover, Ltd. and I.C.I. Ltd.)

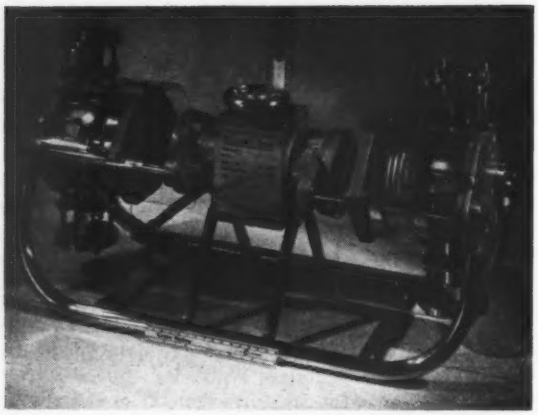


Fig. 17. Bellows pump by Crane Packing, Ltd. with p.t.f.e. bellows (I.C.I. Ltd.)

polythene insulation and p.v.c. sheathing are common. For high frequencies, such as t.v. relay cables (Fig. 15), polythene "foam" was developed, and where abrasion resistant sheaths are needed, nylon comes into its own. If extreme chemical or heat resistance is necessary, p.t.f.e. can be used and p.v.c. compounds can be produced with special non-migratory plasticisers for critical situations. Polythene found a large outlet in radar, and more recently transAtlantic telephone cables were laid, using it as dielectric.

P.t.f.e. is used for valve and coil holders for v.h.f. applications, and whole circuits or sub-assemblies are often potted in resins so that a complete spare can be carried and "plugged in" if a fault develops. Printed circuits are another facet of the lighter class of engineering in which plastics play their part.

On the heavier side, polyester film is used, generally in conjunction with pressed paper, for slot liners in motors (Fig. 16). Chokes and transformers are insulated with it as it is unaffected by the oils, and the manufacture of capacitors has already been mentioned.

mechanical and production engineering

Various reinforced laminates have been used by engineers for some time but generally other plastics materials have not had sufficient impact strength or stiffness to find ready acceptance. Recent developments have produced shock resistant materials which we expect will be used more and more.

Nylon gear wheels are used for quietness and where lubrication is difficult or impossible. It is used for door wedges on cars and, on the Continent, for loom beat-up mechanism bowls. Conveyor belting, used in the mines, is coated with p.v.c. Nylon tube for pressure and oil lines finds many outlets, and machine guards are made from p.v.c. and acrylic sheet. Acrylic sheet is also used in aircraft for canopies apart from much interior trim of p.v.c.

chemical engineering

The corrosion resistance of plastics is so good that it would be surprising if they were not used in chemical plant. Ducting, drains and tank linings for corrosive liquids are all natural applications. Polypropylene has recently opened up further possibilities because of its high softening temperature, and engineers have gradually realised that plastics are durable materials and that they do not have to rely on stainless steel. P.t.f.e. is an outstanding material and apart from more conventional applications it has been used as bellows in the pump shown in Fig. 17. The bellows were machined from a solid block of p.t.f.e.

civil engineering

To date only small steps have been made into this, the oldest of the engineering industries. Polythene tube has been used for plumbing, and polythene film has been used as underlay for concrete, for damp courses, and for enclosing buildings in course of erection so that work can carry on even in bad weather. These examples show that civil engineers are turning from traditional materials and are looking at these newer ones with interest. Other examples are provided by p.v.c./fibreglass rainwater goods, plastic foams for insulation, and combinations of p.v.c sheets with foams for curtain-walling.

Here is a challenge for one of the newest and one of the oldest industries to join together in exploiting unique materials that have found so many uses elsewhere.

FIRST B.C.A.C. ANNUAL LECTURE

The first annual lecture inaugurated by the British Conference on Automation and Computation is to be presented by *Dr. D. G. Christopherson*, O.B.E., F.R.S., Pro-Vice-Chancellor of the University of Durham and Warden of the Durham Colleges.

He will speak on the subject "*Mathematics - Friend or Foe?*" in the Lecture Theatre of The Institution of Electrical Engineers, Savoy Place, London, W.C.2., on *Wednesday, 27th September*, 1961, at 5.30 p.m.

The Lecture is open to all 31 member societies of B.C.A.C. (of which The Institution of Production Engineers is one). Tea will be served at 5 p.m.

MODERN TECHNIQUES IN PLASTICS MOULDING

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This Paper was presented to the London Section of The Institution of Production Engineers in March, 1960.

THE rapid growth in popularity of plastics materials can be attributed not only to the specific properties of attractive appearance, lightness in weight, resistance to corrosion and toughness which they offer, but also to the relative ease with which articles can be produced from them. The very term "plastic" implies a shapeable material, and it is this easy mouldability into even the most complex form which is one of the main reasons for the oustanding success of plastics in recent years.

As a preliminary to a survey of the moulding techniques commonly in use in the industry today, distinction must be made between the so-called "thermosetting" and "thermoplastic" types of material. Moulding of the latter is a purely physical process. Thus they are softened by heat to allow shaping into the desired form, and subsequently hardened by cooling. The thermosetting materials can similarly be softened and formed by heat, but at the temperature used for moulding, a chemical reaction takes place, and it is this process which brings about hardening. In the hardened condition the moulding is infusible, unlike that from a thermoplastics material which can be softened by heat. Perhaps the best known example of the thermosetting class is phenol formaldehyde moulding powder; well-known thermoplastics are polythene, polymethylmethacrylate ("Perspex"), polystyrene and polyvinylchloride.

Irrespective of the type of plastics material involved, the first requirement of any moulding process is the

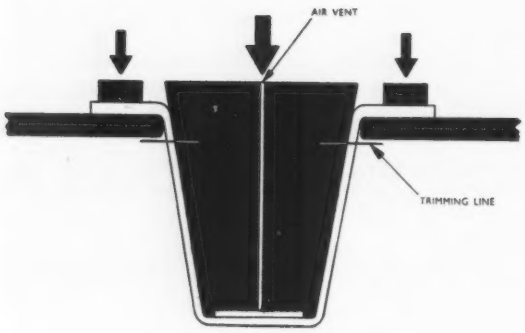


Fig. 1. Simple pressing

provision of heat to bring it into a suitable state for shaping. Thus either the mould itself must be heated, or alternatively some technique adopted for softening or melting the material before it is fed to the mould. It will be evident, however, that it is hazardous to adopt the latter procedure with thermosetting plastics because of the likelihood of premature solidification and heating *in situ* is preferable. With thermoplastics, on the other hand, alternate heating and cooling of the mould is inconveniently slow and laborious, and is rarely employed in practice.

The technique adopted mainly with thermosetting materials whereby heating and shaping are carried out with the mould itself is commonly known as compression moulding. There are, however, two variations to the method of handling thermoplastics materials, dependent on whether they are available to the moulder in flat sheet form, or the form of a powder or granules. The thermoplastics made in sheet form are of a type which become rubbery, but not liquid, at temperatures in the range 100-200°C. In the softened state the sheets are still sufficiently form stable to be handleable, and can be transferred manually or mechanically to the mould maintained at a lower temperature, where forming into the desired shape can be carried out under suitably applied pressure. This technique is known as thermo-forming. Granular thermoplastics on the other hand are converted by heat into a softened mass, or highly viscous liquid, and forced under high pressure through a small aperture in the mould. This is most commonly carried out by actuating a plunger in a cylinder placed adjacent to the mould, and is referred to as injection moulding.

The three main methods of plastics moulding indicated above are considered in more detail below. In each case the basic principles are first outlined, and then in the light of an assessment of the factors likely to limit the rates of production obtainable, the processes used in present-day practice are surveyed.

thermo-forming

Unlike injection moulding, which normally involves the use of special self-contained automatically operated equipment, thermo-forming is quite commonly carried out by a manually linked sequence of operations using relatively simple standard equipment. Thus the only essential requirements are a heating oven (e.g. air-flow, infra-red, or convector type), a press, and a compressed air or vacuum supply, for applying the force required during shaping. The fact that only relatively low temperatures and pressures are required gives rise to a wide choice of materials for mould construction. Thus in addition to metals, wood, phenolic laminates, plaster etc. can be used, the choice depending on such factors as the required life of the mould, and the optical quality (if a transparent material) and surface finish desired. Similarly, considerations of the shape and size of the article involved, the material to be used, thickness distribution, surface finish required and so on, will determine the shaping technique employed, i.e. whether pressing, blowing, sucking or a combination of these is used. Some simple techniques are illustrated in Figs. 1, 2, and 3.

Considering now the factors which determine the rate of production in thermo-forming processes, of obvious importance are the times taken to heat the sheet to shaping temperature, and required to cool the moulding to a temperature sufficiently low that loss of shape does not occur when the constraining action of the mould is removed. For most purposes sheet temperatures in the range 120-170°C are required, and with relatively thick sheets (i.e. $\frac{1}{8}$ to $\frac{1}{4}$ in.) heating times of the order of 15-30 min. are necessary. Attempts to heat the sheet more rapidly may result in decomposition of the material. The cooling time will depend upon the sheet temperature

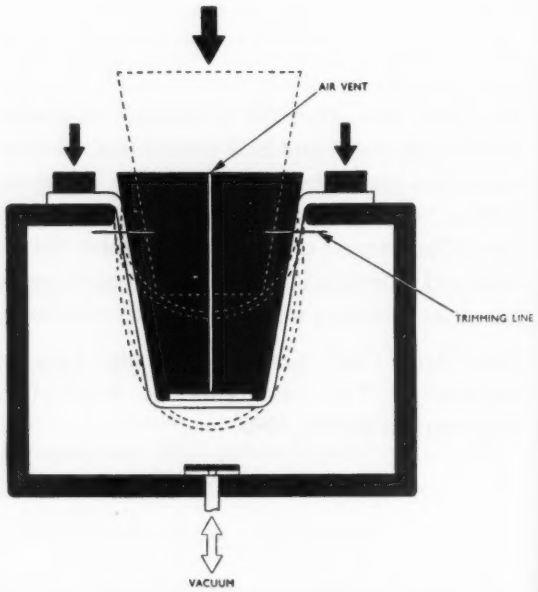


Fig. 2. Vacuum-assisted pressing

prior to shaping, the mould temperature, and with some shaping techniques, upon the area in contact with the mould. As would be expected, metal surfaces allow a more effective removal of heat, but rapid cooling is often undesirable if optimum properties are to be obtained in the moulding. Too cold a mould may also cause splitting during the shaping operation. For most purposes a mould temperature in the range 40-70°C is used, resulting in cooling times of the order of 5 min. Appreciably longer times may be necessary in instances where the rate of cooling must be restricted to obtain the best optical qualities in transparent materials.

Naturally, as the thickness of the sheet is reduced, so do the heating and cooling times become shorter, and with very thin sheets of the order of say 0.030 in. thickness, heating and cooling times can be enumerated in fractions of a minute rather than minutes. Under such circumstances, high rates of production are possible, and it becomes desirable to automate the process to reduce handling time. This is achieved in the so-called vacuum forming machines. These are in effect low, i.e. atmospheric, pressure, self-contained thermo-forming machines, and a typical layout is shown diagrammatically in Fig. 4. The main components are an infra-red heater, usually mounted on a horizontal track so that it can be moved into position as required, a mould bed plate and clamping frame, and of course a vacuum pump and reservoir. There is also very often provision for compressed air, used for piece ejection purposes and for blowing over the moulding to accelerate cooling.

The type of work which can be carried out in the simple assembly shown in Fig. 4 is rather limited, but by the provision of auxiliary gear other shaping techniques can be employed as desired. "Drape forming" (a procedure developed to offset the often unacceptable thinning in mouldings made by the simple vacuum forming process) is carried out using a vertically moving mould base as shown in Fig. 5. A variation of this, which gives even better uniformity of thickness, is the so-called "bubble" or "air-slip" method, in which the softened sheet is pre-stretched

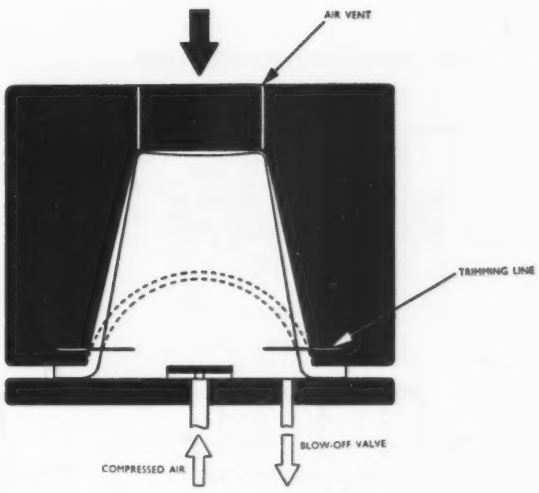


Fig. 3. Blowing into a female mould

by blowing before it comes into contact with the mould, as shown in Fig. 6. Under circumstances where it is necessary to introduce a local deep draw into an otherwise relatively flat moulding, a plug can be provided for pressing purposes (Fig. 7).

In these general purpose vacuum-forming machines the various stages of the operation, i.e. the heating, application of vacuum and so on, can be controlled automatically, so that the only manual operations are the loading of the sheet and the subsequent removal of the moulding. With suitably pliable materials, many machines can be adapted to allow sheet to be fed continuously from a reel, thus allowing completely automatic operation to be achieved. The more elaborate equipment includes auxiliary gear for cutting and trimming the shapings as they leave the forming machine.

1. *Heater*
2. *Sheet Material*
3. *Soft Rubber Gasket*
4. *Clamping Ring*
5. *Mould Box*
6. *Mould*
7. *Air Vent*
8. *Vacuum Line*
9. *Air Line*

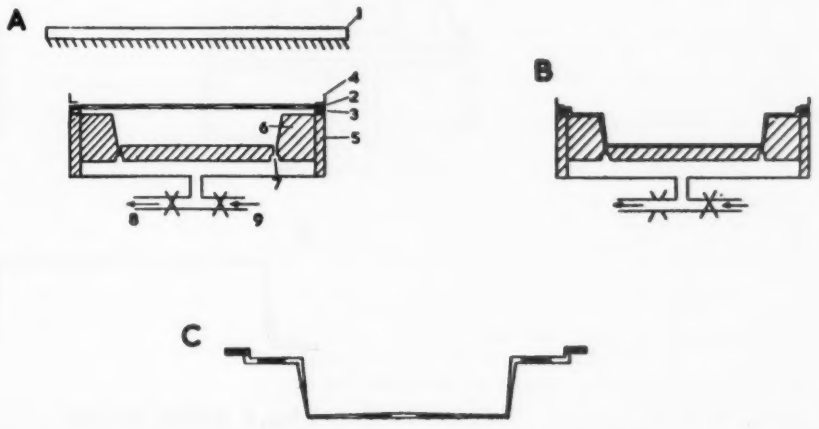
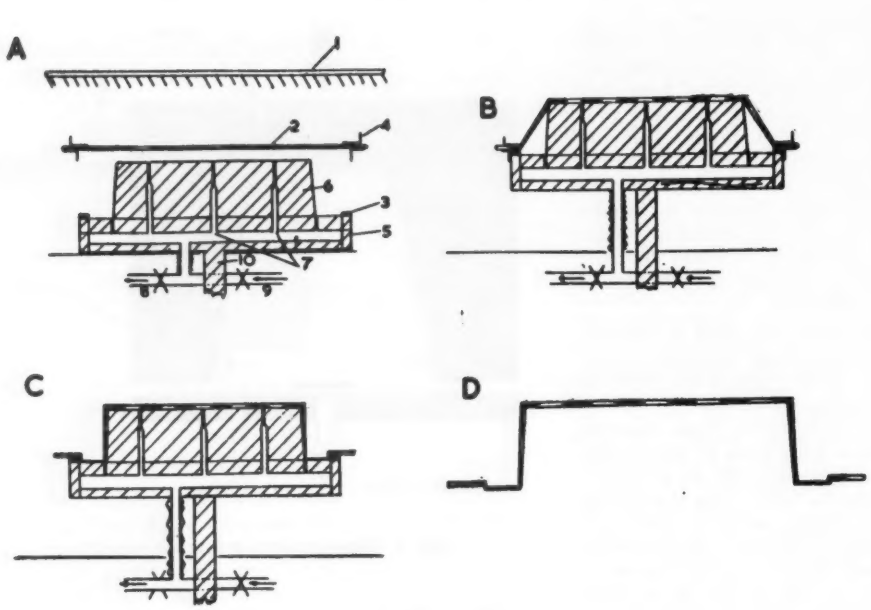
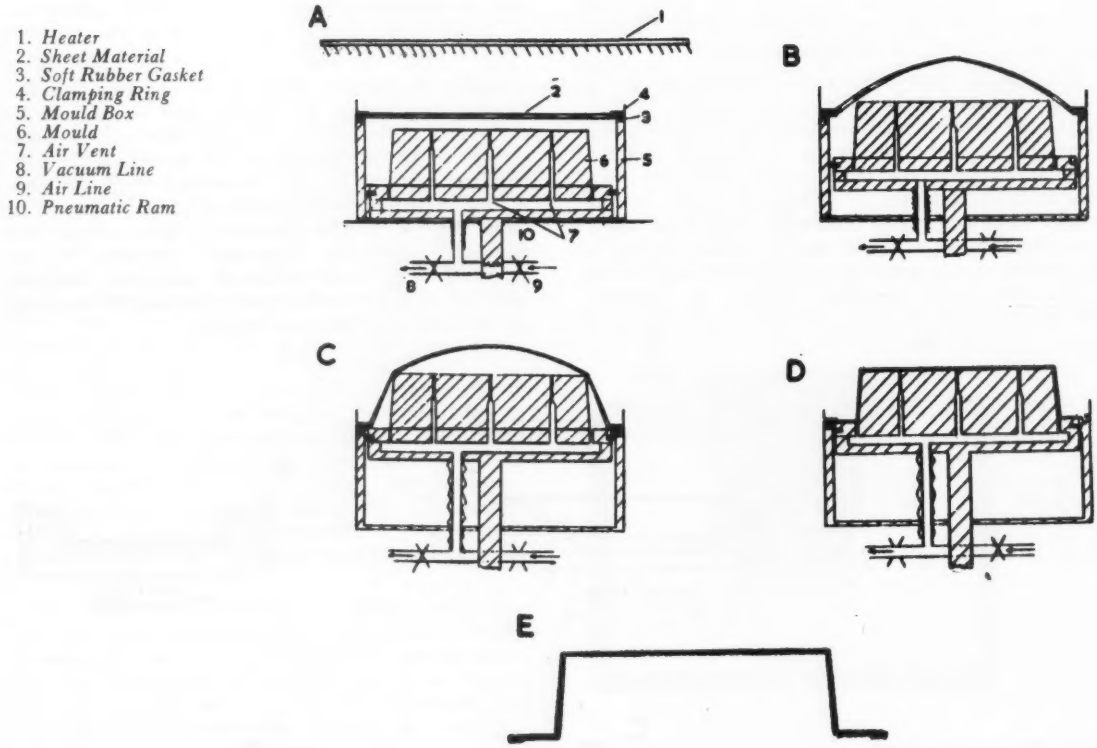


Fig. 4. Vacuum forming (female mould)



1. *Heater*
2. *Sheet Material*
3. *Soft Rubber Gasket*
4. *Clamping Ring*
5. *Mould Box*
6. *Mould*
7. *Air Vent*
8. *Vacuum Line*
9. *Air Line*
10. *Pneumatic Ram*

Fig. 5. Drape forming



1. *Heater*
2. *Sheet Material*
3. *Soft Rubber Gasket*
4. *Clamping Ring*
5. *Mould Box*
6. *Mould*
7. *Air Vent*
8. *Vacuum Line*
9. *Air Line*
10. *Pneumatic Ram*

Fig. 6. Bubble forming

1. *Heater*
2. *Sheet Material*
3. *Soft Rubber Gasket*
4. *Clamping Ring*
5. *Mould Box*
6. *Mould*
7. *Air Vent*
8. *Vacuum Line*
9. *Air Line*
10. *Pneumatic Plug*

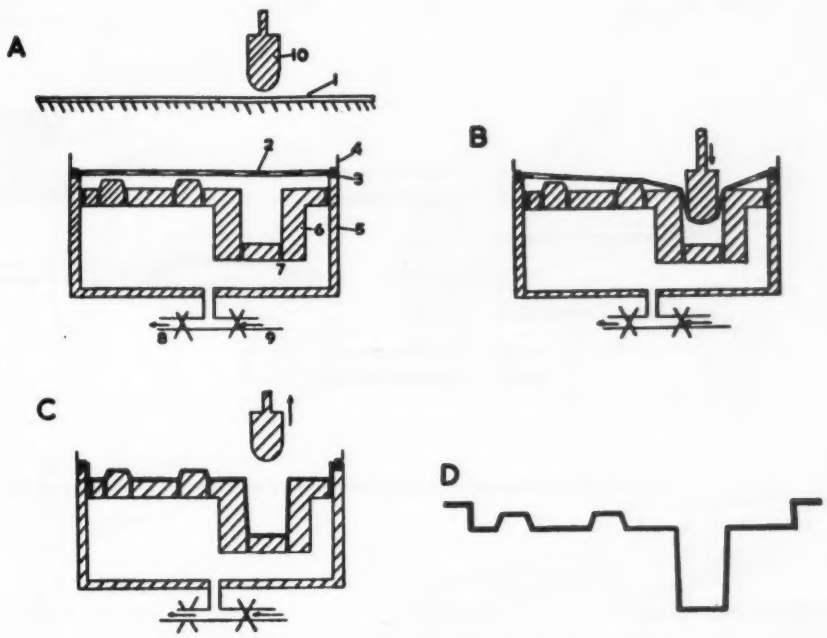


Fig. 7. Plug-assisted forming

The next logical development of the continuous process is to eliminate the necessity for heating the sheet by linking the forming machine to a sheet manufacturing plant. Thus by means of a large screw extruder, sheet of the required thickness is produced and while in the unchilled, still soft state, moulds are arranged to cycle to and fro along the direction of take-off, allowing shapings to be made without interrupting the continuous flow of the sheet. Such an arrangement has been used in the United States in instances where the quantities required have warranted the installation of relatively costly equipment.

Reverting for a moment to the semi-automatic general purpose type of machine described initially, it will be appreciated that increased outputs can be achieved by using twin or multi-unit systems. A twin unit machine would normally consist of two moulding stations placed back to back, with a single heater unit cycling backwards and forwards, enabling heating to be carried out at one station, while forming and cooling is taking place at the other. In a triple unit assembly the whole operation is carried out on a rotating turn-table. Thus the cycle commences with the loading of the sheet at the appropriate station. It is then indexed to a heating station, thence to a forming station, finally returning to the initial position for unloading.

A recent further development of the vacuum forming machine is automatic thermo-forming equipment fitted with powerful double-sided heaters, and with facilities for higher shaping pressures than that obtainable by vacuum, to render it capable of handling sheets of thicknesses of the order of $\frac{1}{8}$ in. These machines are expensive in relation to the cost of the equipment required for the simple manual methods described earlier, and their use is only economically feasible if very long runs on the same article are required. It should also be borne in mind that in some instances where mass production working is required, the alternative technique of injection moulding might be more suitable on a cost basis. Lighting fitting diffusers, motor-cycle and scooter wind-shields, and television implosion guards are typical examples of articles required in relatively large numbers where very careful investigation of the relevant economics is required in making a choice between traditional manual thermo-forming techniques, automatic thermo-forming, and injection moulding. Finally it should be appreciated that even using the traditional methods of shaping, production rates can be increased by such expedients as using a number of identical moulds served by one operator or, carrying this process to its logical conclusion, by adopting a suitable assembly line procedure.

In general, and certainly as far as Britain is concerned, it may be said that whereas semi-automatic or automatic vacuum forming is used for thin sheets, manual operation is usually preferred for the thick sheets, because of the low capital costs involved providing greater flexibility of operation.

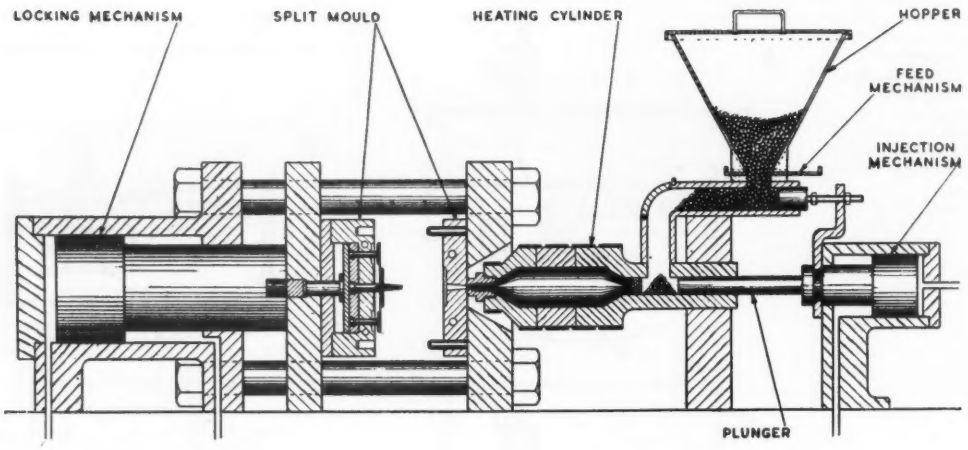


Fig. 8. Diagrammatic representation of an injection moulding machine

injection moulding

In terms of quantities of materials involved, injection moulding is the most widely used method of manufacturing plastics articles. It is invariably carried out on automatically or semi-automatically controlled equipment, and a commonly used type of machine is shown diagrammatically in Fig. 8. It will be seen that the essential features are a cylinder fitted with electric resistance, or sometimes induction heaters, which serve to soften the granular plastics material and bring it to the moulding temperature of 150-300°C, when it is forced near the wall under the influence of the central torpedo-shaped obstruction, a plunger actuated by hydraulic pressure generated from an oil pump, and a cooled mould the two parts of which are fitted to massive platens held together during the filling operation by a suitable locking force. The usual cycle of operations is as follows :—

1. The ram is moved forward to compress the unmelted granules at the rear of the cylinder, subsequently developing sufficient pressure to displace the molten material at the front end through the nozzle and into the mould. At the same time a subsidiary plunger linked with the ram introduces a metered charge of fresh granules into the cylinder.

2. Injection pressure is maintained for a predetermined period of time to ensure that fresh material can flow in as the moulding contracts under the chilling influence of the mould. In particular when making thick mouldings, it is necessary that the gate, i.e. the entrance to the mould cavity, should be of such a size that it does not freeze prematurely, so preventing this stage from being carried out effectively.

3. The ram returns to its original position, and when sufficient time has elapsed to enable the component to become sufficiently rigid to be removed without deformation, the mould is opened, and the piece removed either manually or by a suitable ejection device.

4. The mould is closed and the sequence of operations recommenced as before.

The time the ram remains forward is usually called the "injection time" or "dwell time"; the period between the end of this stage and the mould opening is referred to as the "cure" or cooling time. Both are controlled by process timers. In semi-automatic working an operator is required to start off each cycle of operations, but facilities for fully automatic working are available on most modern machines in instances where no manual handling in the ejection of the component is involved.

It should be noted that in contrast to thermo-forming, injection moulding is of necessity a high pressure process. Most modern machines of the type described are capable of exerting pressures up to at least 20,000 lb./sq. in. and the stiffer plastics materials such as polymethylmethacrylate ("Diakon") and certain types of p.v.c may in fact require pressures of this order of magnitude. This means that the equipment must be robust, well built, have a well designed hydraulic system, and hence be relatively expensive. Unlike thermo-forming, there is little scope for the moulder to assemble his own equipment; it must be obtained from a specialist machine manufacturer. Similarly the moulds must be sufficiently strong to withstand the pressures involved, and be machined to close tolerances to ensure effective mating of the mould surfaces and avoid "flashing". The incorporation of cooling channels is necessary to obtain effective removal of heat under rapid moulding conditions. The best quality moulds are made from chromium plated hardened steel and cost anything

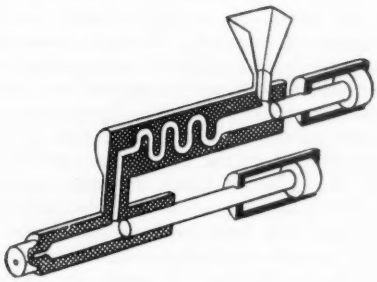


Fig. 9

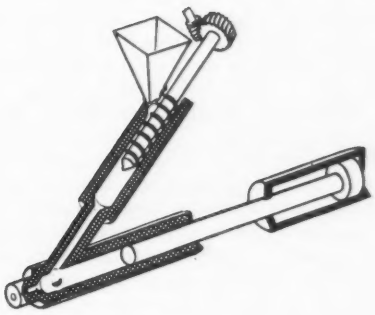


Fig. 10

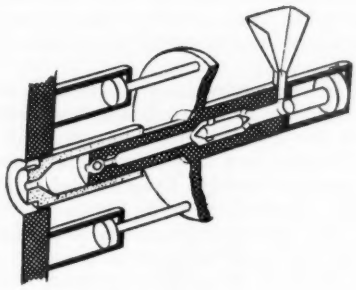


Fig. 11

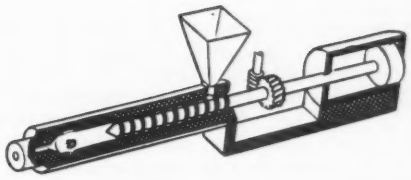


Fig. 12

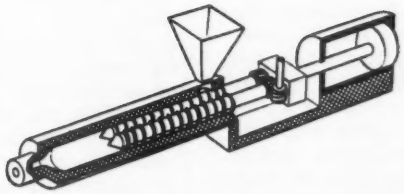


Fig. 13

Pre-plasticising injection moulding machines (courtesy of "British Plastics")

from a few hundred pounds for small components to several thousand pounds for large complicated articles.

All this means in effect that injection moulding is essentially a mass production method, which is rarely economic unless quantities of the order of tens of thousands or more are required. For quantity production, however, it can be a very cheap method, since output rates are high, and little is required in the way of skilled supervision. Unlike thermo-forming, the trimmings and other waste portions from the moulding can readily be re-used by regranulating and feeding back into the cylinder.

The overall cycle time is determined by the rate at which material can be melted in the cylinder, or by the rate of cooling of the moulding, whichever is the slower of the two processes. With thick section mouldings, or plastics which solidify at relatively low temperatures, rate of cooling is normally the limiting factor; in other instances it is the rate of melting. In general, however, cycle times are very much shorter in injection moulding than in thermo-forming, since the method of softening is a more efficient one, and rates of cooling are greater, since the moulding can be formed much more rapidly and brought into intimate contact with a cool metal surface. Overall times vary from a few minutes in the case of large thick mouldings, to a few seconds in the case of small thin section mouldings. In instances where rapid melting and cooling make very short time cycles feasible, the time involved in operating and moving parts of the machine, i.e. the ram and the mould, become of significant importance, and in the so-called fast cycling machines these operations are

speeded up by use of high displacement pumps in the hydraulic system. Another time-saving device in such circumstances is to arrange for the ram to commence its travel before the mould is completely closed.

The type of machine illustrated in Fig. 8 is of a design which has remained essentially unchanged since the earliest days of injection moulding, some 20 or more years ago. It is still found to be perfectly satisfactory for many purposes, but experience has shown that, particularly for making large mouldings, it has a number of serious drawbacks. As the diameter of the cylinder is made larger in order to obtain increased shot capacity, so does it become increasingly difficult to melt the granules at the correspondingly increased rate desired. Attempts to increase rate of melting by lengthening the cylinder, or by introducing larger and more complex obstructions, aggravate another defect of this system, namely, the losses in pressure which occur between the plunger face and the nozzle. The initial compression of the unmelted granules retards build-up of pressure at the nozzle, and pressure losses result from the movement of these granules against frictional resistance from the cylinder wall and torpedo. The disadvantageous effects of a slow build-up of pressure can be mitigated by rapid ram movement, or by introducing spring-loaded valves into the nozzle or mould gate, but it is evident that the most efficient transference of pressure can only be obtained if the space between the ram and the nozzle is filled with molten plastic only. This means in effect that the melting must be carried out as an independent operation, and the obvious way of doing this is to link up with a separate pre-melting chamber.

A system of this type is shown diagrammatically in Fig. 9. It will be seen that the torpedo has been removed from the injection cylinder, and where the hopper normally feeds unmelted granules, a pipe has been attached linking the injection system to a pre-melting cylinder. The latter incorporates a long narrow flow path to obtain rapid heat input, and a hydraulically operated plunger is provided to force the molten plastic into the injection cylinder. Since the injection ram acts on molten material only, pressure losses are virtually eliminated, and maximum ram face pressures need only be of the order of 10,000 lb./sq. in., as compared with double this value in the conventional system. The absence of pressure losses also give rise to a more consistent nozzle pressure value and hence a more consistent quality of product.

The particular design illustrated in Fig. 9 can be achieved by modifying a conventional machine; other systems of the same general principle are also built as integral units. As an alternative to a ram in the pre-melting cylinder an extrusion screw is used in some machines (Fig. 10). Because of the mixing action of a screw, very high rates of melting can be achieved by this method.

The use of two chambers rather than one naturally increases the size and cost of construction of the machine, and for this reason much thought has been given to the question of fitting them together in as neat and simple a way as possible. In the so-called "in-line" system shown in Fig. 11 the pre-melting cylinder fits inside the second cylinder, acting as a ram for injection purposes. Similarly, several manufacturers have been successful in designing machines in which both operations are carried out within the same chamber. Such a system is illustrated in Fig. 12. As the screw inside the injection cylinder rotates, pulling in granules from the hopper, it can move backwards in the cylinder filling the space ahead of it with molten plastic. At a suitable stage it stops rotating, hydraulic pressure is applied, and it then acts as a ram for injection into the mould. The machine shown in Fig. 13 works in an identical fashion, but incorporates two intermeshing screws rather than the one as shown previously. These single-chamber screw type machines have become increasingly popular in recent years, since in addition to giving rapid melting and the other advantages of pre-melting systems, they are very suitable for incorporating pigments and dyestuffs to make coloured mouldings.

It should be emphasised that pre-melting, or pre-plasticising machines as they are usually called, have not replaced the conventional type since the latter are usually cheaper, and very often more convenient for general purpose work, in particular when making small articles. Individual pre-plasticising systems have their own specific advantages and disadvantages, and the choice between them is largely determined by the type of article involved, and the particular plastics material or materials it is desired to use.

extrusion moulding

In connection with the use of moulding machines incorporating a screw rather than a ram, reference should also be made to systems in which mould filling is achieved simply by rotation of the screw. Since no axial motion is used, only relatively low pressures (3-4,000 lb./sq. in.) are developed and mould filling capacities are limited unless fairly hot moulds are used. The low pressures involved are an advantage in that cheaper mould construction becomes possible, and it is mainly for this reason that the method has been widely used for the manufacture of plastic shoes, where the multiplicity of sizes and shapes involved would render the tooling costs inordinately high in conventional injection moulding. In a commonly used machine of this type high production rates are achieved by indexing the moulds on a rotating turn-table.

blow moulding

Hollow articles such as bottles cannot, because of their shape, be made in one piece by injection moulding and involve far too deep a draw for thermoforming from sheet. Air-blowing the molten material inside a suitable mould, as in making glass bottles, is however feasible, provided a suitable preform is first made. This preform can be made by injection moulding, but more commonly a length of extruded tubing is used.

The principle of extrusion blow-moulding is illustrated in Figs. 14 and 15. A plastics extruder is fitted with a cross-head to enable the molten tube to fall

vertically downwards between the two halves of a mould. When the mould closes around the tube, air at a pressure of the order of 50 lb./sq. in. is blown in, usually either through a hole in the centre of the extrusion die or through a metal tube inserted into the base of the mould. Blowing through the die normally necessitates the mould assembly remaining close to the die throughout, and with a simple set-up of the type shown in Fig. 14 extrusion must be stopped during blowing and cooling. High output rates can, however, be achieved by using multi-impression moulds and multiple extrusion heads as shown in Fig. 16. Blowing through the base of the mould has the advantage that immediately the tube is enclosed it can be severed from the die and the mould can be moved away, allowing extrusion of further tube to continue while the moulding is being shaped and cooled. Thus machines have been developed in which the mould is mounted on a platform which can reciprocate vertically beneath the die, or on a carriage for similar operation in a horizontal plane. Alternatively a number of moulds can be mounted on a rotating turn-table as shown in Fig. 17.

Blow moulding is an inherently high speed process since rapid and efficient melting is obtained in the extruder and, with simple bottle shapes at the least, the moulding operation involves little or no flow along the walls of the mould, allowing low temperatures in the mould to be used, giving rapid rates of cooling. Cycle times of the order of seconds are normal in plastics bottle production. Mouldings are easily ejected from the mould at the end of the cooling stage, enabling fully automatic working readily to be achieved. The duration of the various stages of the moulding sequence (blowing, cooling, moulding removal, etc.) is determined by process timers.

Automatic blow moulding machines are roughly similar in cost to injection moulding machines of comparable size. Moulds are, however, cheaper, since the pressures involved are negligible by comparison with those required for injection moulding, hence permitting less robust construction. Non-metallic moulds can be used for prototype work or short runs, though for normal production purposes, metal

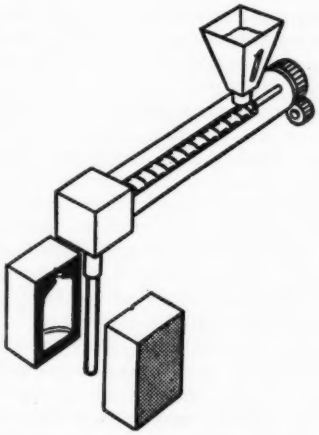


Fig. 14

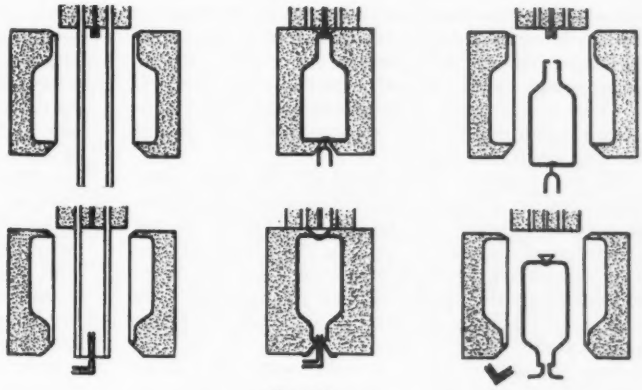


Fig. 15

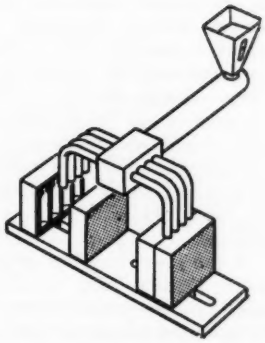


Fig. 16

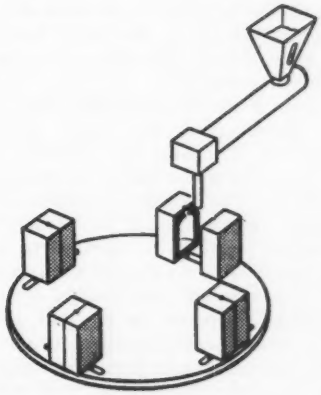


Fig. 17

Extrusion blow-moulding (courtesy of "British Plastics")

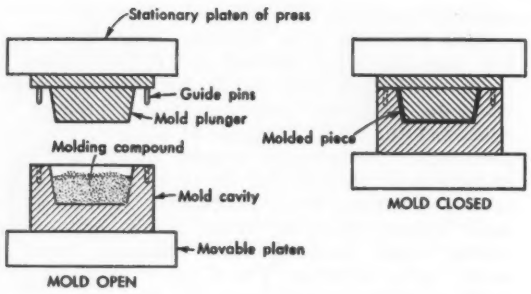


Fig. 18. Compression moulding

moulds cored for water cooling are required to give the highest output rates.

compression moulding

As indicated earlier, this method is used mainly for the moulding of the thermosetting types of plastics such as urea formaldehyde and phenol formaldehyde materials. The basic equipment is shown diagrammatically in Fig. 18 and will be seen to consist simply of a two-part mould fixed to the platens of a hydraulic press capable of exerting pressures of the order of 4,000 lb./sq. in. The mould is maintained at a temperature in the range 120-170°C, dependent on the particular material to be used, by electric or steam heating of the platens, and prior to closure charged with powder, or a pellet of the correct weight cold pressed from powder. The use of pellets is less messy than powder, and under production conditions allows a more accurate control over the weight of charge.

The cycle time is determined by the time taken for the powder to heat to moulding temperature, for the mould to close as the material flows to the extremities of the cavity, and for the curing process to be completed. Overall times (i.e. from the commencement of the mould closure to injection) vary from about 30-60 sec. in the case of small mouldings such as bottle caps, to about 5-10 min. in the case of large mouldings such as toilet seats. It will be evident that since there is such a marked difference in cycle time between small and large mouldings, the time taken for heat to be transferred to the powder is a limiting factor in the latter instance. For this reason methods of pre-heating outside the mould have been developed.

Although it was said at the outset that an irreversible chemical reaction takes place during the moulding of thermosetting plastics, this reaction occurs to a negligible extent at temperatures below about 100°C. The powder or pellets used can therefore safely be pre-heated at these relatively low temperatures, cutting the subsequent cycle time by as much as 50% in the case of some large mouldings.

Powder is normally pre-heated in a rotary drum using electric elements or gas jets, whereas pellets are more conveniently handled in a high frequency pre-heater using a radio frequency field. The rate of heating is usually adjusted to fit in with the moulding cycle, i.e. one charge is being pre-heated while the previous one is being moulded. In addition to reducing moulding cycles, pre-heating improves surface finish in many instances and reduces the incidence of flow lines. Because the material is nearer to moulding temperatures when the mould closes, flow is easier, reducing mould closure time and, if desired, enabling working pressures to be lowered. Of course, care must be taken that the material is not overheated during this preliminary stage, otherwise some "curing" will occur, making flow in the mould very difficult.

In the manual operation of a compression press the time taken to make one moulding, or impression of mouldings, is appreciably longer (50-100%) than the mould operating time (usually referred to as the "cure" time), because of the time involved in loading the charge and subsequently removing the moulding. Fully automatic presses are, however, available with facilities for automatic loading of pellets from a hopper and for automatic injection. Since these operations are carried out much more rapidly than is possible by manual methods, output rates are increased particularly with small mouldings which have relatively short "cure" times. The only manual operation required is the recharging of the hopper, and one operator can supervise several presses.

Automatic operation of this kind is commonly used for the manufacture of small components such as bottle caps, overall cycle times of the order of 1 min. being achieved which, together with the use of multi-impression moulds, make possible the obtainment of high output rates. Another approach to the problem of obtaining high output rates of small mouldings is to use a large number of single impression moulds on a rotating turn-table. These are indexed in turn to a loading station, the mouldings being ejected at a subsequent station at the rate of possibly one every second. Rotary machines of this type are in common use in North America, and can be operated with a very minimum of supervision.

In general it may be said that using automatic presses, output rates of small mouldings can sometimes approach those obtained in injection moulding of thermoplastics. With large mouldings they are lower because of the lower rates of heating and the time involved in loading and clearing manually operated presses. On the other hand, the cost of large manually operated presses is very considerably less than a comparably sized injection moulding machine, possibly by as much as a factor of ten. Mould costs for the two processes are comparable.

(continued on page 616)

CRYSTAL FILAMENTS

by W. S. HOLLIS, Ph.D., B.Sc., A.F.R.Ae.S., M.I.Prod.E.

Assistant Director, Aircraft Production Development,

Ministry of Aviation.

ALTHOUGH the growth of the crystal filament was noted by Boyle, the propounder of the classic Gas Law, in his famous work "The Sceptical Chymist", the phenomena of their growth did not become seriously studied until metallic whiskers became a hazard in practical engineering in the middle 1940's among firms constructing miniaturised electronic equipment. This growth was found to account for inexplicable short circuits.

The possible use of crystal filaments as a structural material has been studied only in the last few years. Examination of the structural strength of whiskers showed that they approached more nearly the theoretical strength of the metal and about 100 times that obtained from tensile tests of bulk specimens.

The difference between the actual and theoretical strength of a pure, single crystal is explained by the presence of irregularities in the atomic structure, termed dislocations. The theory for this atomic disarray was presented by G. I. Taylor (1) in England during 1934 and was confirmed by Orowan, who had approached the dislocation theory independently. This led to the abandonment of the concept of the perfectly arranged crystal lattice structure and explained observed data related to electrical and diffusion phenomena, the strength and plastic behaviour of metal. It also provided the path for examination of crystal growth.

An easily readable approach to the definitions of the atomic structure, the character of the vacancies dislocation theory, etc., is given by Hume-Rothery (2) in the form of questions and answers, and is recommended as an aid to the better understanding of the subject.

Whiskers may be produced in a variety of ways, such as electrolytic deposition from a molten salt, condensation from vapour, or the reduction of salts by heating in the presence of hydrogen, or precipitation from solution. Silver whiskers can be obtained by heating silver sulphide. Zinc, cadmium and tin coatings from hot dip or electro deposition will provide whisker growth (7). Chlorides and bromides when heated with hydrogen form halides and produce whisker growths as long as 3 in. The Tube Investment Research Laboratory (5) has reported that organic and inorganic salts produce needles which derive from precipitations in the form of thin whiskers. Growth by cleavage of lithium fluoride crystals is also reported.

Whiskers possess generally rectangular, rhomboidal or symmetrical polygon cross-sections and derive from a single crystal growth. The filament or leader gains in dimension about three orders faster than its cross-section. The filament possesses a thickness between 1 and 50 microns (.00004 in. – .002 in.) and can nucleate and grow in a heavily supersaturated vapour at the rate of 2 microns/sec. The basal growth of tin whiskers may be as low as 1Å/sec.

Growth mechanisms are defined as predominantly tip or basal. With tip growth a change is represented by a branch growth of a tree; basal growth produces the height of the trunk. Preferential attachment of molecules will occur at the tip (Fig. 1) but an occasional molecule will condense and attach to the side of the filament, giving rise to a fresh tip growth.

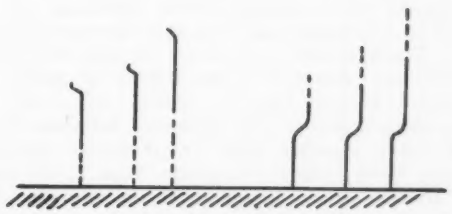


Fig. 1. (right) Tip and (left) basal growth of a crystal filament

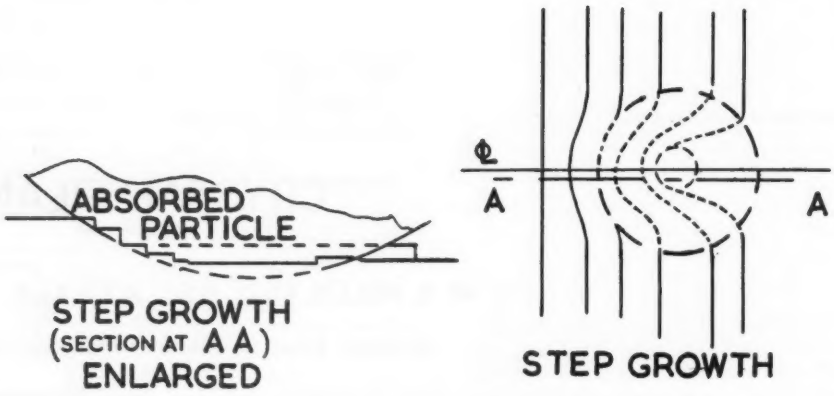


Fig. 2. Step growth on a crystal face

Preferential growth at the tip has been explained as due to the formation of screw dislocations. Where, for example, an atom nucleates on a smooth surface of a crystal, others will attach and the process of nucleation and growth will proceed rapidly across the surface, especially if the surrounding vapour or solution is in a heavy super-saturated condition. The growth thus proceeds in steps, but when each step is completed further nucleation is retarded until a few atoms can attach without dispersal into the vapour phase for a sufficient length of time to initiate a fresh step. An atomic disarray which provides a screw dislocation, however, offers a continuous irregularity of the surface which will not impede the rate of crystal growth even at low values of super-saturation. This phenomena was observed by Frank (3), who showed that so long as the dislocation intersects the surface, the crystal contains a permanent growth step and atoms condensing on the surface are able to deposit in a region of atoms, which, by exhibiting a preferential attachment at the step, adhere as neighbours. Thus the growing layer will spiral around the screw dislocation.

Mitchell has reported on the electrolytic formation of metal fibres. Treating crystals of silver chloride where screw dislocations were believed to be present, it was found, during reduction of silver halides, filaments of 0.1 micron diameter were formed.

Price, Vermilyea and Webb (6) have shown on the basis of theory and experiment that when a crystal is exposed to a super-saturated medium, growth occurs in a movement of steps over close-packed surfaces. The available steps which advance the crystal growth are, however, those having a radius of curvature greater than a critical minimum, r_c. Thus where a step growth encounters adsorbed molecules closer together than $2r_c$ it cannot advance between them; where r is greater than r_c the steps will advance freely to create crystal growth. (See Fig. 2.) Generally it is shown that the larger adsorbed molecules have a lower vibration characteristic and are more likely to remain attached sufficiently long to become adsorbed and buried. A steady state condition of growth of the crystal is defined as where the rate of burial of molecules in the step process is equal to the rate of their attachment. Impurity molecules also diffuse, are adsorbed and incorporated into the crystal structure.

The mechanism of basal growth is not so fully understood. Precipitates cause the whisker to gain length, the process being likened to an extension or extrusion from the surface. There appears also to be no explanation for the random configuration along the length of the filament. Tapered whiskers exhibit many disorientations.

The growth of tungsten oxide needle crystals has been observed at 30,000 mags. by means of electron

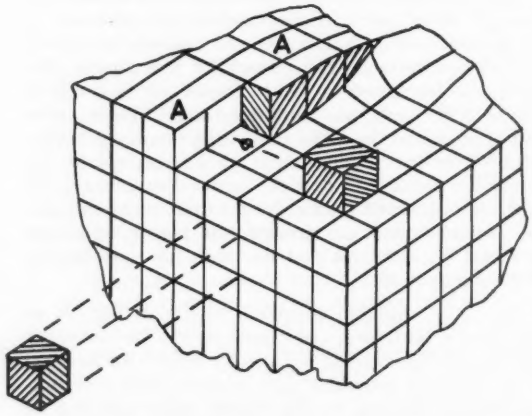


Fig. 3. (i) The screw dislocation provides a growth step at AA. Precipitating atoms lodge at the step so long as the dislocation intersects the surface. A spiral growth proceeds with the formation of each step.
(ii) Atoms condense with difficulty on the smooth side walls of the crystal.

microscopy. A tungsten wire filament, when heated in the range of 700°C-1000°C in a vacuum of 10^{-4} mm. Hg. produced a growth, the mechanism of which was thought to consist of a bundle structure of single microcrystalline growths whose orientations varied within some limiting range (8).

When heated to 1100°C in the same vacuum the needles began to evaporate either at the tip where a candle-wick like appearance developed, or the side walls were subject to apparent random attack.

The facts were concluded to indicate that individual microcrystalline needles, which form the bundle structure crystal filament, corrode independently by a mechanism which is, in a sense, the reverse of the growth mechanism which consists of tip growth and wall thickening.

Restriction of growth mechanism of the filament to one, or at most, only a few dislocations, tends to explain the reason for its high tensile strength. In the single crystal structure produced by the spiral growth there are few available dislocations which can be presented in the direction of an applied stress; thus the normal slip and twinning mechanisms which accompany plastic deformation are not present. As may be expected from this, the transition from elastic to plastic deformation of the filament will be abrupt and will be accomplished by the introduction of a fresh system of dislocations in the structure, effected by the deforming force. (See Fig. 4.) In the plastic phase, therefore, the loss of strength in the filament will be precipitate and will approach more nearly those results experienced in testing of normal metals. Larger diameter specimens have a longer plastic phase than those of 3 μ and below. The strength of the filament has also been observed to diminish with time, this being considered as due to the development of edge dislocations arising from the onset of oxidation. Soluble impurities have been introduced without appearing to affect the stress/strain value.

A table of comparable strength between whiskers and bulk metal is given at Fig. 5. The phenomenal strength of the crystal filament has led to investigations to employ them somewhat on the lines adopted with glass fibres; attempts at joining, other than by

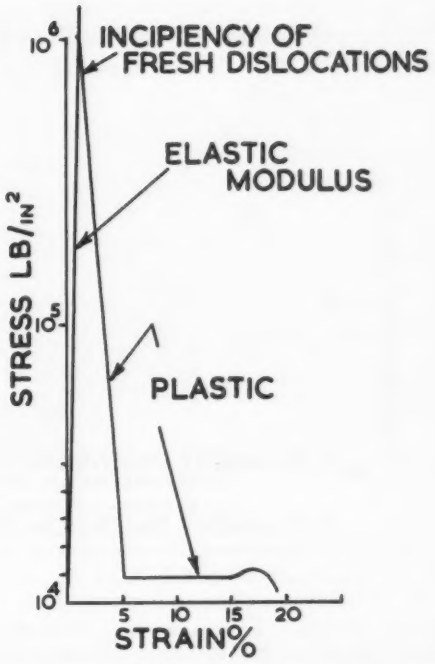


Fig. 4. Stress/strain pattern for a metal whisker

cold welding, would produce large non-filamentary crystals possessing normal physical properties. Bonding in a matrix which would provide for their alignment appears to be a more practical proposition. Essentially the diameters of fibres in a strand would vary but would possess the same modulus and density. Variation in peak elastic strength would be governed by a selection of maximum permissible stress below those values related to the larger cross-sections. To ensure adherence, the matrix would require a lower modulus and higher ductility than the embedded fibre. Comparative values of thermal expansion and deterioration of strength with rise of temperature

Material	*Whisker Strength* lb./in.²	*Bulk Metal* lb./in.²	*Theoretical Strength* G/2π–lb./in.²
Iron	$1{\cdot}96\times10^{6}$	2×10^{4}	196×10^{6}
Copper	4×10^{5}	2×10^{4}	1×10^{6}
Beryllium	3×10^{6}	4×10^{4}	$3{\cdot}7\times10^{6}$
Alumina	$1{\cdot}2\times10^{6}$	8×10^{4}	—
Graphite	3×10^{6}	4×10^{4}	—
Silicon	$5{\cdot}5\times10^{5}$	5×10^{3}	—
Silicon Carbide	8×10^{5}	—	—
Tin	—	—	4×10^{5}

Fig. 5. Table of relative strength of filament and bulk materials

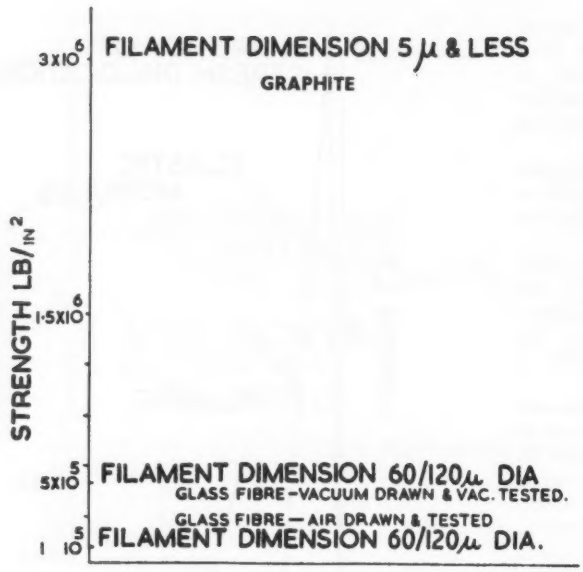


Fig. 6. Comparative strengths of grown crystal filaments and those drawn

must be considered in avoiding internal stress in the matrix; work in this direction indicates that the selection of the binder may be made from plastic resins which can be used up to 300°C, or boron polymers which may extend the temperature limit to 600°C. Electrolytic deposition of metal binders may be practicable.

Essentially the modulus/density, $(\frac{E}{\rho})$ value is the determinant in comparing the crystal filament with metallic and non-metallic materials commonly used in construction. The unit strength of the filament will increase with reduction of its diameter and in this connection it may be possible to produce, with advantages in cost, finely drawn strands of micron dimensions which will possess a tensile strength approaching that of the crystal filament. (See Fig. 6.) Fig. 7 shows comparative values of tensile strength with dimensional cross-section and this figure can be compared with that showing the energy to remove a

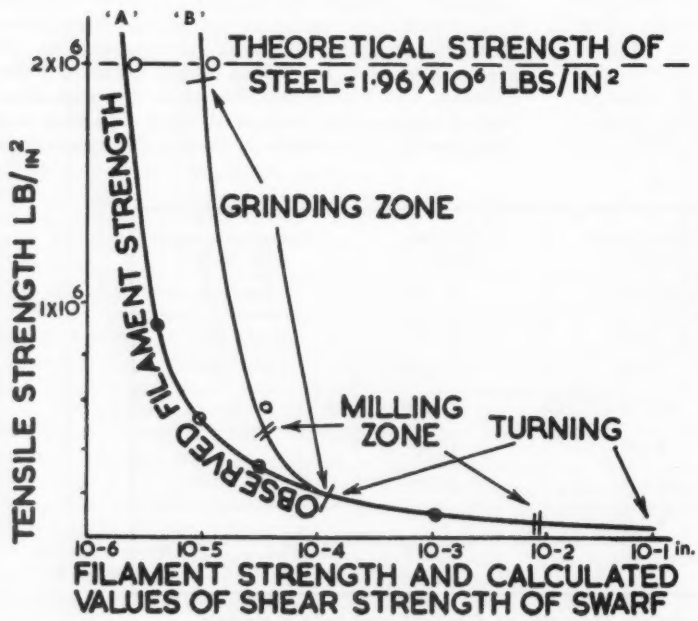


Fig. 7.

Graph A. Observed strength variation of iron filaments of varying diameters

Graph B. Calculated strength of steel swarf derived from chip forming processes (smallest particle dimension)

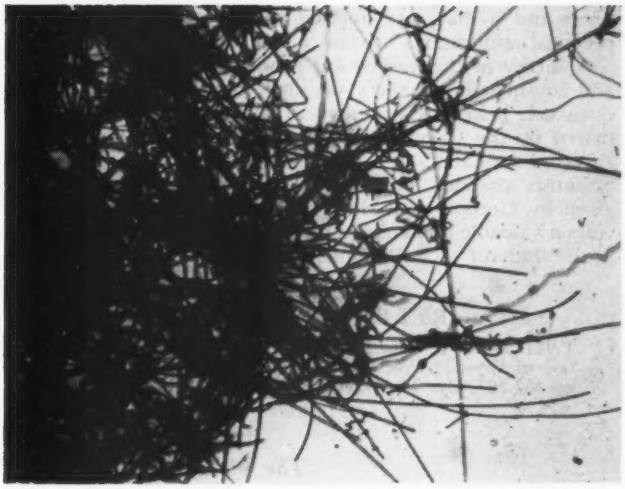


Fig. 8. Photomicrograph of silicon nitride mass of fibres which present an appearance similar to cotton wool, several of which show a regular spiral form (X 270)

unit volume of metal by the available cutting processes. The maximum theoretical strength obtainable is given by $\frac{G}{2\pi}$ where G is the shear modulus of the material.

The whiskers which are most likely to be useful in terms of high modulus and low density are carbon, boron carbide, boron, silicon carbide, aluminium oxide and beryllium. Carbon has the highest strength weight ratio among these, and its properties are maintained above 2,000°C. The remaining materials fall away in strength between 800 and 1,000°C.

The properties of the composite strand produced from filaments and binder will be highly directional and the application in construction is likely to follow the methods adopted for fibre glass. The disadvantages of cost of production is likely to eliminate the material from reinforcing applications in the civil engineering field.

Cost estimates for manufacture are reported to be as high as 10 or 20 times the cost of other airborne materials, but with a strength/weight ratio approaching 1/50th of that encountered in steel construction there are obvious advantages in its use.

Reports from all sources indicate that the study of crystal filaments is very much in the fundamental stage and it will be some time before applied research into the cropping, weaving, bonding and sizing can be undertaken. It is observed however that the pattern follows that relating to the utilisation of glass

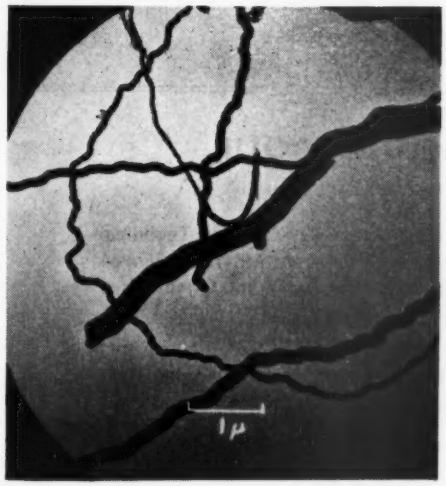


Fig. 9. Electron micrograph of fibres formed on pre-nitriding (X12,000)

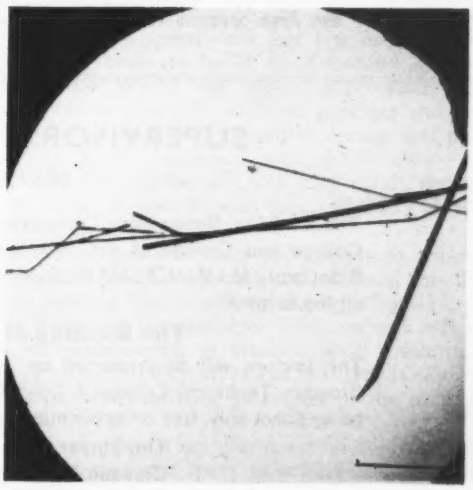


Fig. 10. Electron micrograph of fibres α-Si_3N_4,(X5000)

fibres and it may take another two decades before practical applications become a reality.

A survey of the mechanical properties of metallic and non-metallic whiskers was made the subject of a discussion held at Cambridge in March, 1958, and shared by the Cavendish Laboratory and the Tube Investments Laboratory. Some 60 British and U.S. Scientists attended and a summary of the Papers is given by Gordon and Menter (4). The report provides a valuable reference to British scientists engaged in the study of crystal filaments.

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ACKNOWLEDGMENT

The photomicrograph and electron micrographs (Figs. 8, 9 and 10) are published with the permission of The Director of The British Ceramic Research Association, Stoke-on-Trent.

"Modern Techniques in Plastics Moulding" —continued from page 610

A disadvantage of thermosetting materials is that "flash" and other waste portions cannot be re-used, though these can be kept to small proportions by good mould design and accurate control of charging weights. A counter-balancing factor is that "flash" can be removed from compression mouldings by a tumbling operation, whereas in injection moulding waste portions must often be removed manually.

summary

Injection moulding is the most widely used method of fabricating plastics articles because of its versatility in terms of sizes and shapes of articles which can be made, the high output rates possible, and the relatively low operational costs involved. It is, however, suitable for quantity production only since equipment and tool costs are high. Thermo-forming, on the other hand, though giving lower output rates, can conveniently be used for short runs because of lower capital costs. Vacuum-assisted thermo-forming is a simple and often quite rapid method of making hollow articles of thin wall section. Compression moulding must be used for thermosetting materials. In this process output rates of large mouldings are lower than in injection moulding, though by use of fully automatic presses small mouldings can be made at a speed approaching that obtainable in the latter process.

SUPERVISORS' DISCUSSION GROUP

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The Croydon Supervisers Discussion Group, in conjunction with Croydon Technical College and College of Art, have arranged a lecture to be given by *Mr. T. W. Bunyan* B.Sc(Eng)., M.I.Mech.E., M.I.Ma.E., Engineering Advisor to the P. & O. and Orient Lines on the subject:

"The Building of a Great Passenger Liner"

The Lecture will be presented on Tuesday, *3rd October*, 1961, in the Denning Hall, Croydon Technical College & College of Art, Fairfields, East Croydon. Admission will be by ticket only, free on application to:

The Bursar or Enquiry Office,
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Fairfields,
East Croydon.

The Grinding and Setting of Tangential Roller Box Tools

A Thesis by

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THE tooling layout design draughtsman, when concerned with the speedy removal of material by turning, together with a good quality finish, to tolerances to a minimum of plus or minus 0.0015 in., will often specify tangential roller box tools in preference to the radial type, particularly when only limited clearance between other tooling is available. This is often the case, for example, with turret type automatic screw machine and capstan lathe set-ups.

The success of this tool in operation is largely dependent on the skill of the toolsetter in correctly grinding and setting initially, and subsequently resetting correctly after reproducing the original form of tool when regrinding is necessary.

It is generally accepted production machine shop practice for high speed steel tool bits used in tangential roller boxes to be off-hand ground and set by toolsetters. Whilst the writer appreciates that toolsetters have divergent ideas on grinding and setting roller box tools and do achieve results that pass inspection, he is concerned with the tendency in many machine shops of well-tried and proved designs to be abused by the "pet wrinkles" of the toolsetting fraternity.

Roller box tools are designed primarily to remove the greatest possible amount of material in the shortest possible time, whilst producing a highly burnished finish on the diameter being turned. It is often in endeavouring to attain a good finish that tools are altered to such an extent that they no longer conform to the governing principles of the original design.

A study of these principles would no doubt reduce considerably the time spent in setting and resetting before the desired results are achieved. For instance, a toolsetter may grind a square section tool for a tangential roller box quite correctly and then, for no

apparent reason, spoil it entirely by backing-off the trailing edge from the cutting point. The failing of this tool in operation, due to lack of support behind the cutting point, will then have to be corrected by uneven roller pressure, causing unnecessary wear of the toolslide and workspindle bearings, and producing very inconsistent results.

There are many similar examples in operation where tool faults are being corrected by unorthodox setting and where a good workpiece produced is a matter more of luck than a predetermined certainty.

Low overall productive efficiency is often tolerated by supervision where tangential roller boxes are included in a set-up, because of the inability of the toolsetters to master the several essentials to their successful functioning, often through lack of correct tuition. It is with the latter in mind that this Thesis has been written, in the hope that it may benefit users of tangential roller box tools.

correct positioning of tool

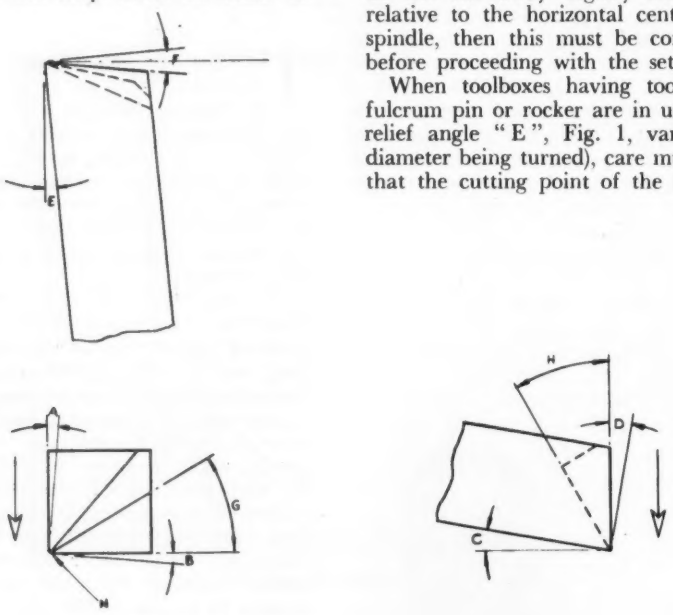
Tool nomenclature varies considerably in different localities and machine shops and even between individual toolsetters on the shop floor. In order to clarify the expressions referred to in the text, a typical tangential tool is depicted in Fig. 1 with a key to terminology.

The cutting face and trailing edge (in plan) of a high speed steel tangential tool should form a right angle, i.e. it should have no plan relief angle (A), and no side cutting edge angle (B) (see Fig. 1). It should be so set in the toolbox that it is presented squarely to the workspindle (tilting of the tool away from its square seating as it is being tightened may be prevented by using set pins having conical or spherical ends).

The cutting point of the tool must be set at the centre line of the work, but both cutting edge and trailing edge should have slight positive back-rake (Angles (F) and (D), Fig. 1). This condition can only readily be seen when the tool is in position in the toolbox because it is influenced by the clearance angles of the cutting face and trailing edge, which are a predetermined design feature of the toolbox (Angles (C), (D), and (E), Fig. 1).

If, on placing the tool roughly in position, it is apparent that the cutting edge and/or trailing edge do not fall away slightly from the cutting point relative to the horizontal centre line of the workspindle, then this must be corrected by regrinding before proceeding with the setting.

When toolboxes having tool adjustment over a fulcrum pin or rocker are in use (i.e. where the end relief angle "E", Fig. 1, varies according to the diameter being turned), care must be taken to ensure that the cutting point of the tool is set so that its



A	PLAN RELIEF ANGLE
B	SIDE CUTTING EDGE ANGLE
C	SIDE RELIEF ANGLE
D	TRAILING EDGE ANGLE
E	END RELIEF ANGLE
F	CUTTING EDGE BACKRAKE
G	V LIP ANGLE
H	CUTTING EDGE SIDE RAKE
N	NOSE RADIUS..

FIG.1. TANGENTIAL TOOL (RIGHT HAND CUTTING)

height is such that it lies in an imaginary arc, passing through the centre line of the work with the centre of the fulcrum pin, or rocker, as its centre. (See Fig. 2.)

error compensating angles

The angle of the trailing edge relative to the axial centre of the work (Angle (D), Fig. 1) plays an important part in correcting resultant taper on the diameter being turned, which may be caused by inaccuracies of machine alignment, worn toolslides or workspindle bearing, etc., and may be adjusted accordingly by the toolsetter to produce parallel turned diameters despite these deficiencies. For example, if the diameter being turned is correct to size at the commencement of the cut, and progressively smaller as the cut proceeds, this condition may be corrected by proportionately reducing the degree of positive angle of the trailing edge (back-rake) from the cutting point and increasing it for a reverse taper condition. (See Fig. 3.)

chip clearing tool lip

Cast iron and most non-ferrous materials may be turned with tools having no chip clearance other than normal cutting rakes. But when turning steels, chip clearance in the form of a truncated V-shaped lip is required to ensure that the material being removed leaves the tool in a continuous coil while the cut is in progress.

The lip is formed in the top of the tool by offhand grinding, using one corner of a squarely dressed plain grinding wheel. Starting to grind at the opposite side to the trailing edge (in plan) and taking repeated cuts, the V being formed is arranged to meet the cutting, trailing edges, and cutting point simultaneously.

It is essential that the apex of the V does not break through the trailing edge or a secondary cut will be taken by the tool in operation. This, although possibly initially producing a good finish, will ultimately clog or spoil the finish of the rollers. If when nearing completion of the lip the trailing edge is broken through, the top of the tool must then be reground to reproduce the correct rakes and the lip reformed in it. During this and all grinding operations on the tool, it is essential that it is kept cool by frequent quenching or its cutting life will be impaired.

Proprietary brands of high speed tool bits are often declared by toolsetters to be of poor quality when, in fact, they have been ruined by the toolsetters themselves through overheating the steel when offhand grinding and drawing the temper of the cutting face.

The tool will cut cleanly with minimum power requirements when the lip terminates as closely as possible to the trailing edge without breaking through it. Except for special applications a nose radius is unnecessary (see Fig. 1). Chip coil diameter will be related to the feed rate and the width of the lip behind the cutting point. A lip that is too narrow will cause the chip stream to break up in short lengths and at each break a concentric line will appear on

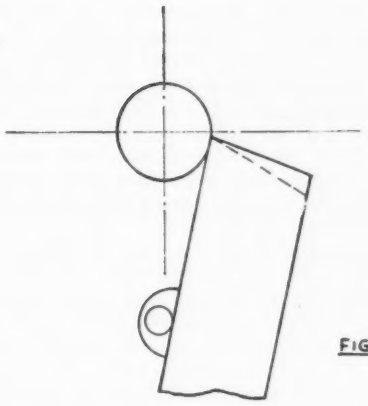


FIG. 2.

the finish of the work. Ideally, the chip stream should leave the tool in a closely packed continuous helical coil. The use of chip breakers on high speed tools is not recommended.

The angle at which the chip stream leaves the tool may be varied by altering the angle of the V relative to the cutting edge; this will also alter correspondingly the degree of positive rake of the cutting face and may be adjusted to suit the material being turned. In general, for free cutting materials, more positive rake angle (i.e. the chip stream leaving the tool almost parallel with the cutting face) may be used than for materials that quickly break down the cutting edge. For the latter condition, the degree of positive rake should be reduced to support the cutting edge and is accomplished by commencing to grind the V lip towards the back of the side of the square opposite the trailing edge (in plan). The chip stream will then leave the tool in a more backward direction. (See G and H, Fig. 1.)

rollers and roller setting

The cutting face of the tool should be ahead of the rollers—a distance slightly in excess of the feed per revolution of the cut being taken, usually between 0.010 in. and 0.020 in. for controlled feed rates. For tangential roller box tools being used on hand

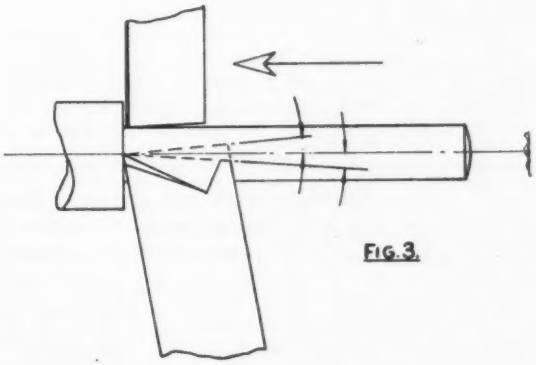


FIG. 3.

operated slides, this distance may be adjusted to regulate the feed rate of the cutting stroke. The feed per revolution may be governed by packing out the roller carriers until the cutting face of the tool to roller distance equals the feed rate required. As for this application the rollers will be contacting the shoulder of the material being cut, their front faces should be slightly dished so that their rotation is controlled by the diameter being turned, and not by the material face.

For maximum support, a pair of rollers should contact the work at 90° and 180° respectively to the cutting point of the tool, but deviations occasioned by the use of double roller carriers with fixed centre roller centres of up to 20° will not affect results. Rollers should work at a pressure equivalent to 0.003 in. to 0.005 in. of the diameter being turned. This pressure will be sufficient to result in a highly burnished surface finish on B.S.S. 970 steels, non-ferrous materials, cast iron, and alloy steels, and should not be exceeded.

A pair of rollers should work at equal pressure. They are most accurately set by first reducing the diameter required by 0.003 in. to 0.005 in. (using fine feeds for the unsupported tool), adjusting roller carriers until the rollers are just making contact with this reduced diameter, and finally, adjusting the tool to cut the required diameter. Once set in this manner and properly tightened, roller carriers should require no further adjustment until the toolbox is disturbed in its setting in the turret or slide. Providing rollers meet the specification outlined below, any discrepancies in results may be attributed to errors in the tool or the tool setting.

Rollers must be concentric with the pins on which they rotate; the slightest ovality will affect results. A pair of rollers must have matched radii on the leading corners and the dimension from the leading radii to the back face must also be matched so that the burnishing work is shared equally. End play between rollers and their retaining carriers will not affect results providing no secondary cut is being taken by the tool. This, as stated above, would ultimately clog them.

The resultant finish on the surface of the work is directly proportional to the finish of the contact surface of the rollers. It is pointed out that the tool is the medium for the removal of material only; the rollers create the surface finish.

Rollers should have a tapered surface of approximately 2°, the major diameter with its radius being the only effective working portion of roller surface. Almost a line contact behind the cutting edge of the tool, a little in excess of the feed per revolution of the cut, is the ideal condition; therefore leading radii on rollers for general use should be between 0.010 in. and O.030 in.

effects of using parallel rollers

Parallel rollers, except under conditions of almost perfect machine alignment and rigidity, will cause endless difficulty in setting and maintaining and should not be used for normal tangential roller box tool work.

Errors in workspindle to toolslide alignment, out of square roller carriers or roller pins, and worn toolslides and/or workspindle bearings, will influence results if parallel rollers are used, particularly on long slender workpieces. This is because the work is supported to a certain extent in line with the initial lift, or "push-out", at the commencement of the cutting stroke and, as the cut proceeds, gradually assumes a "mean line" as the stock becomes more rigid towards the front workspindle bearing. As a result the turned diameter is tapered and poorly finished due to the trailing edge "shaving" the work as the cut proceeds and, in addition, causing deep return marks on withdrawal.

Roller diameters should be as large as clearances allow. On most commercial toolboxes roller diameters are approximately 1½ times the largest diameter the box will turn. This is to enable adjustment to be effective over a range of diameters, the lower limit being reached when the rollers no longer rotate freely due to mutual interference.

further important considerations

At the commencement of its cut a tool is unsupported until the rollers make contact with the diameter being turned. Therefore when practical the stock should have a radius or chamfer "lead on" for the tool.

Roller box tools must be kept cool during the cutting stroke with copious supplies of coolant—volume rather than pressure is required.

conclusion

From the foregoing it will be evident that attention by toolsetters to the essential requirements outlined will result in the grinding and setting of tangential roller box tools being accomplished without experimentation and consequent loss of productive time.

Although commercial toolboxes vary considerably in design, particularly with respect to pre-set angles and tool adjustment media, adoption of the basic grinding and setting procedure outlined above must inevitably follow if their efficient use is to be achieved and maintained.

Correspondence and comment on published Papers and matters of interest to production engineers are invited.
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EFFICIENT UTILISATION OF MATERIALS

—AN ANSWER TO THE EXPORT CHALLENGE

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A Paper presented to the Welsh Regional Conference of The Institution of Production Engineers in Cardiff, on 5th May, 1961.

IN the nineteenth century Britain's industrial supremacy in the then known markets of the world was almost unchallenged. Our products carried a hallmark of design and quality unsurpassed, and also recognised and accepted as the best in the world.

Up to 50 years ago our merchants could accept as payment for their goods, coin, precious metals, precious stones and valuables, and we were the pioneers of world barter trade. Our position of value and quality supremacy in world markets often engendered in us an attitude of arrogance and superiority in our approach to the foreign customer. On the other hand, we were also noted for being the most lavish business entertainers in the world, and nearby Cardiff Castle is an example of the extent to which we were prepared to entertain the overseas customer.

In the post-war period (only ten to twelve years ago) the challenge to every factory (even prodded by national posters) was epitomised in the slogan: "How much production?". Today the challenge of exporting necessitates the reversal of this same slogan into: "Production at how much?". We have learned that there is a very great difference between increased production and increased productivity. The challenge of "Export Now" has shown us that high costs of production are not only a threat to individual businesses, but are detrimental to our world trade and to the living standards of the nation.

In selling the idea of increasing productivity and extending our sales and export markets, not only must we educate our customers to the advantageous

features of our products, but also educate our employees to the fact that consistent quality, good delivery and competitive costs are the only means of deriving security of employment and a higher standard of living.

For our future industrial prosperity it is not sufficient to fill present demands in existing markets, but necessary to create and develop new demands in the potential markets of the world. There are no easy markets for our products and the overseas markets are tougher than the home market, but there are many promising markets for good value British goods and service.

The motivating power to production must be progressive selling. Without effective sales in world markets there can be no future for production. In fact increased productivity without expanding markets can be a formula for depression, and we could discover that we are getting the right answer to the wrong question.

The President of the Board of Trade in his address "EXPORTS—WHOSE MOVE NEXT?" said :—

"Our import bill, the state of our reserves, the capital outflow, and so on, are reasons so well known, but I would like to stress one point; that is the growing capital outflow from this country in all its forms has to be financed by our export trade."

The Federation of British Industry's recent inquiry into industrial trends, which was carried out in January by questioning 752 Chairmen and Managing Directors in the manufacturing industry, stated : "The chief limiting factor on industrial output has now become a shortage of orders, rather than a shortage of skilled labour".

The President of the Institute of Directors has announced the crusade of "Export Action Now", its purpose being to awaken the public and industry to increase exports.

Essential and praiseworthy as all these exhortations are, there are some limits to export possibilities. For instance, you may make a bicycle the best designed and finest value for money in the world—what do you do when your customer across the Atlantic says :

Fe, fi, fo, fum,
I smell the bicycles of an Englishman;
If his quality is high and his price is low,
Up the tariffs lest his imports grow.

There is also a limit to the number of refrigerators you can sell in Lapland and the number of hot water bottles you can sell in Beirut. But our real national and industrial problem is not just exports; it is the adverse condition of our balance of payments. In fact, we have two strings to our bow—Imports and Exports. How about British industry's challenge to imports?

Let us look at this balance of payments in the light of imports and industry's raw materials.

The raw material of industry, i.e. wool, cotton, timber, rubber and metals, represent 40% of our total national imports (approximate annual import values :—wool £280 million, timber £235 million, rubber £110 million, cotton £130 million, metals £360 million). The Chairman of the English Electric Group of Companies stressed, in his annual report : "We must emphasise that 50% of our costs are for raw materials and manufactured accessories." And of course this is an average figure for industry as a whole.

Now let us look more closely at our own industrial obligation in this challenge of balancing payments by efficient utilisation of materials.

You will be aware of the pioneer work undertaken by our Institution of Production Engineers, in which research into material utilisation in the metalworking industries showed that in an analysis of present-day production costs of consumer goods material costs can represent 30 to 40% of the factory cost. More important is the fact that this survey in a range of metalworking industries revealed that the proportion of the gross material purchased and converted into the net saleable goods was seldom greater than 70% and frequently less than 30%. In fact, an average 60% of the original material purchased is machined or cut away, and this unused material is sold as scrap at between one-half to one-tenth of its original cost.

Efficient utilisation of material demands a change of outlook on manufacturing costs. Often considerable time, ingenuity and expense are involved in designing and making machines and tooling aimed at reducing the direct labour cost by 10%. A 10% saving on direct material would show a much greater cost saving.

Controllable Manufacturing Costs

We all appreciate that manufacturing costs are built up of :—

Labour Costs
Material Costs
Bought Out Items
Overhead Costs

The labour costs are the direct operator and craftsman's time booked to the job, including the preparation time, the time to rectify inaccurate or faulty work, personal inactive time and it could even include wrongly booked time, as well as the actual time doing the job.

So often the assembly time of the product is governed by the standards and consistency of the machining on the component parts. Invariably the machining operations can be mechanised and automatically controlled, but the assembly conveyor can be a myth of mechanisation because so often all the actual operations are hand made. Sub-assembly and main assembly operations are still known in some organisations as "fitting and building" and often, to an embarrassing degree, consist of hand rectification of faulty, inaccurate, or inconsistent machining, or more often to accommodate poor design.

The material costs are built up from the prices paid for the gross amount of material purchased for and issued out on the job, including setting up scrap, ends of bar, and strip machining, and process swarf.

Also any faulty, scrapped, or replaced material, has to be included.

The bought out items can of course range from the screws, nuts and washers to proprietary items, speciality sub-assemblies, packing and cartoning materials, etc.

Overheads are very often a "blanket figure" to cover all the army of indirect labour from office cleaners to office secretaries from gatekeepers to inspectors, and also indirect materials from toilet rolls, and typewriter ribbons, to costly fuels and power.

Taking as examples two widely different products and manufacturing techniques of a domestic product and an aircraft engine, these manufacturing cost figures are :

	Domestic Product	Aircraft Engine
Labour Cost	10%	12%
Material Cost	31%	26%
Bought Out Items	17%	19%
Overhead Costs	42%	43%

Overheads can be anything from 100 to 400% of the direct labour costs, but it is interesting to note that indirect materials such as oil, rag, paper, plating solutions, plant and tooling materials are on average 12 to 15% of the manufacturing costs. Also cartoning, packing, shipping and insurance, can add from 7 to 28% to the manufactured cost. Of course the cost of packing and transport can be considerably controlled by the design of the product and therefore consideration must be given to this aspect because the good designer and production engineer must not limit his interest to the "floor to floor" manufacturing costs, but to the "door to door" costs from the supplier to the customer.

On applying research to this design and production engineering problem of improving the utilisation of material in a domestic product factory, the investigation into the gross quantity of material resulting in the finished product revealed the following percentage of material utilisation :

Sheet and strip material	67%
Bar material	52%
Diecasting	88%
Plastic moulding	82%
Paint and enamel	27%

On a visit to America I found American industrialists very interested in this new approach, and since my return I have received from one company over there some very interesting figures of their findings

Herr Wankel's Remarkable Engine

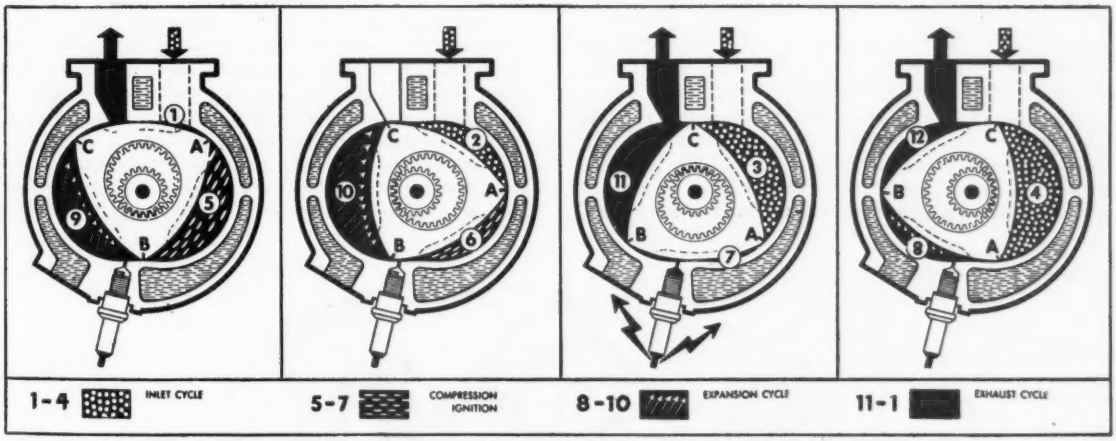


Fig. 1

The rotary piston engine now being developed in Germany by N.S.U. Werke. This drum shaped engine is light and small and develops enormous power in a small space. The 125 cc. prototype produces 29 brake horse power at between 17,000 and 18,000 r.p.m. Its compactness offers new possibilities in car design and its mechanical features promise excellent and economical performance even on low grade fuel. Although they have been working on the engine for six years the inventors are only at the threshold.

Only two things rotate—the piston and the output shaft which are so geared that one revolution of the piston turns the shaft three times. The three spaces between the sides of the piston and the walls of the casing form three chambers and as the piston rotates the shape of these chambers constantly changes.

WHAT IT COSTS
(OFF THE PEG AT A MULTIPLE)
30% - CLOTH - £6 · 0 · 0
30% - PROFIT MARGIN - £6 · 0 · 0
17·5% - DIRECT LABOUR - £3 · 10 · 0
10·0% - OVERHEADS - £2 · 0 · 0
8·75% - TRIMMINGS - £1 · 15 · 0
3·75% - PURCHASE TAX - 15 · 0
RETAIL PRICE £20

Fig. 2

resulting from an investigation into plastic material and paint utilisation :—

Plastics	*Material Utilisation*
Transfer moulding	68.2%
Separate cavity moulding using powder	87.9%
Separate cavity moulding using preforms	93.1%
Cellulose acetates (thermoplastics)	98.9%
Enamel	
Hand spraying methods	17.5%
Dip painting methods	64.7%
Electrostatic methods	73.3%

Investigations into this aspect of cost reduction have indicated that often it is not only a question of the value of the material in the product, but rather the ratio of material utilisation to the original material purchased. The difference between the weight and value of the gross amount of material purchased and the nett amount of material that goes into the final product could represent the cost that would price a product out of the export market.

These cost figures and statements indicate quite clearly that the challenge to our designers and production engineers is to "build into" our products consistent quality and to "build out" unnecessary costs by attacking overhead costs and material costs.

In designing and production engineering to achieve consistent quality and controlled costs the aspects in which to direct Management and Research are in :—

(A) Reducing Overhead Costs
(B) Maximum Utilisation of Materials

and both of these objectives can be achieved by :

1. **Reduction in the size of the product**
2. **Reduction in the number of components**
3. **The minimum production process or operations**
4. **The minimum material removal operations**
5. **The use of new materials and processes**

1. Reduction in the Size of the Product

Product design research, recently developed materials and new manufacturing processes offer the designer and production engineer tougher and more consistent materials, combining strength, lightness and rigidity. This has led to the miniaturisation of components and the compactness of products. For instance, compare a one-horsepower electric motor made in 1930 with a present-day one-horsepower motor, and you will see it has been reduced in size and weight by almost 50%. But right now an ingenious electrical manufacturer in France has developed an F.H.P. motor that is two-thirds the size and cost of our present-day F.H.P. motor. This will mean that motor-driven products such as motor pumps, car heaters, vacuum cleaners can be considerably reduced in size. Again an air fan invention by a German engineer has been developed by a well-known British electronic group and this is one-third the weight and size of the conventional air fan. This will make it possible to design air heaters and coolers of less than half the present size, a hairdrier the size of an electric shaver and, it is claimed, a self-contained vacuum cleaner not much heavier than a broom.

The newly developed transistor has led to the design of a combined hearing aid and spectacle frame and is also the basis of the compact portable radio

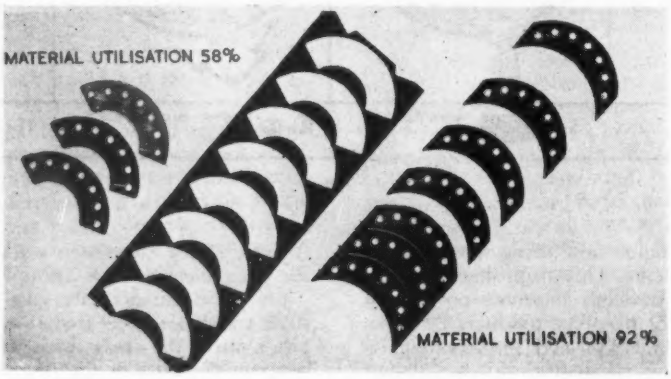


Fig. 3

set. Television tubes of the 70° design were 23 in. long: the 90° tube is 17½ in. long, and the 1960 sales feature was a 100° tube 14¼ in. long, which allows slender line styling of cabinets from 25 in. to 16 in. width.

In fact, bulky and heavy designs may restrict the market. Where compactness is required in order to conserve space as, for instance, in the case of washing machines, refrigerators and aircraft, bulky and heavy designs restrict the market. This aspect is particularly important where a product has to be lifted and carried, a typical example being the modern camera—not until the clumsy plate camera with tripod was replaced by the light folding film type design did the camera industry really require any real production.

2. Reduction in the Number of Components

To quote an example, in one organisation by a combination of design and production research they have reduced the total number of components on one particular product from 764 to 508, and the number of sub-assemblies from 59 to 45, at the same time considerably improving the performance and appearance of the product.

In the original design of a conventional electric motor commutator there were six different parts and a total of 96 components. The redesigned commutator consisted of a total of three parts. The total manufacturing cost of the new design was just 50% of the original design. But the real savings were in material and overheads, less operator training time, a reduction of material in progress, less inspection cost and above all considerably improved and consistent quality. A certain design of a combined fan and clutch sub-assembly was causing considerable factory rejections and also field service complaints. The original design consisted of ten parts and in fact it was the number of separate parts that caused the inconsistency. The sub-assembly was redesigned consisting of three parts and all the factory rejections and field complaints disappeared. The manufacturing cost was reduced from 3/1d. to 2/8d. but here again the real savings were in material and overhead costs.

3. The Minimum Production Processes and Operations

In the early post-war period production engineers rather blindly followed American methods, one of which was to split processes and operations into elements of short cycle times. Invariably this only adds to the overhead and indirect material costs, for instance by combining operations tool costs, setting up time, material handling progress, control time, etc., are reduced. Again, by reducing the range of tapped hole sizes, there is an automatic reduction in drill and tap stocks and always remember, for each tap size there is a plug gauge, thread gauge, drill grinding machine, thread grinding machine, perhaps even an optical comparator to check the thread gauge.

The reduction in the number of production operations or processes can often be achieved by utilising tubular rivets, self-tapping screws and spring nuts to obviate tapped holes. Spot, projection and seam welding can obviate drilled, pierced and tapped holes. While both of these methods are becoming more widely applied, the more modern method of industrial adhesives is not being used to the same extent as by our Continental competitors.

For mechanised and automatic assembly, bolts and screws of even 95.5% perfection in relation to otherwise unimportant dimensions (such as head diameter and depth, screw driver slot width and concentricity) at a speed of 500 screwfixings per hour will mean a machine breakdown of 20 times per 8-hour shift. Adhesives will be the future fixing medium for high-speed mechanised assembling. Again, with such assemblies as brake linings adhesives give greater efficiency with better heat dissipation and a longer linear life. Many modern aircraft like the Fokker Friendship and the Comet IV are designed around the adhesive-bonded metal joint construction. This metal bonding offers new opportunities to conserve materials to the designer and production engineer.

Possibly one of the most expensive production operations is metal finishing (i.e., painting, enamelling, plating, etc.) both as regards preparation work and the very low utilisation of material. The assistance that the designer can give to reduce these costs is in reducing to a minimum the variety of finishes, and standardising in relation to chemical or plated finishes, thus assisting the economics of mechanising the finishing processes. Again, material wastage can be reduced by the designer and production engineer commoning-up and standardising on the undercoats for enamel finishes and by arranging that the variety of finish coats can be baked at a consistent time and temperature. This standardisation of processes will allow the mechanisation of dip, spray and electrostatic application of paint and the conveyorisation of baking process to be economic. The choice by the designer of finishes that have good covering properties, such as the special "two tone" or "hammer" finishes, can eliminate considerable hand fettling and "elbow grease" operations, which again eliminate the use of indirect materials.

The minimum production processes and operations in metal finishing can be achieved by :—

(1) reducing to a minimum the variety of finishes,

(2) standardising chemical or plated finishes that assist the economics of mechanising the finishing processes;

(3) commoning-up and standardising on the undercoats for enamel finishes;

(4) arranging that the variety of finish coats can be backed at a consistent time and temperature so as to aid the mechanisation of dip, spray, electrostatic and baking operations to a conveyorised process.

With all types of coating finishing, the design of the component can assist uniformity of coating, ease of processing and also avoid loss of process materials. Careful design can also provide greater durability

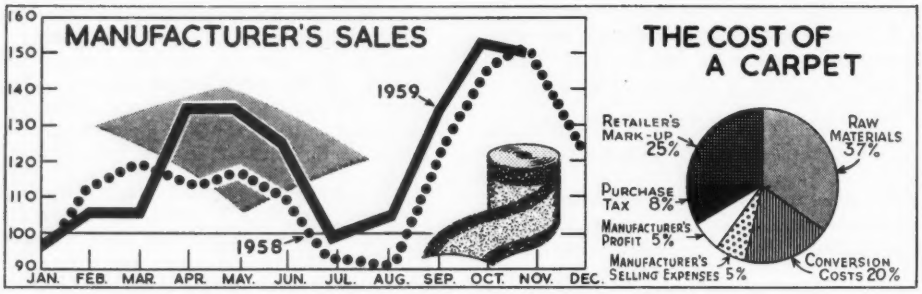


Fig. 4

when in service by elimination of areas where corrosion can quickly start; for instance, avoid rubbing and chafing of plated or painted parts and avoid recesses and pockets that collect moisture. The ideal is, of course, not just skin-deep finishes, but self-finishes such as stainless steel, plastic moulding, thermoplastics, rubbers, glass, ceramics, etc. This really conserves materials.

Another major advantage of self-finish materials is the greater freedom from transit damage and from damage due to abnormal temperature and humidity experienced in overseas markets.

4. The Minimum Material Removal Operations

With the advance of mechanical handling, automatic machine operations, and transfer machine lines, the majority of metal forming and machining operations for large-scale production can be operated and controlled with a minimum of direct operators. However, the maintenance of the cutting tools and the removal of the machining scrap and swarf may need an army of people. The reduction of material removal operations should therefore be the ultimate design and production engineering objective. The motor car industry is beginning to realise that there will have to be some rethinking about automation—automating the conventional machining operations may only mean making the unnecessary become efficient. The industry realises that it must re-evaluate its material utilisation in the light of new techniques, which will mean that the accepted machine shop operations are obsolete.

Our detail designers, draughtsmen and production engineers must apply their Work Study knowledge for the maximum utilisation of materials. Manufacturing processes using machine tools to remove good material because it does not conform to the shape required or because it is surplus to the requirements are costly and may become obsolete.

A particular example (of reducing material removal) is a worm shaft, where the outside diameter of the worm was .846 in., and originally $\frac{7}{8}$ in (.875 in.) diameter bar was purchased, and the worm shaft was machined by the conventional hobbing method. The present method uses $\frac{3}{4}$ in. (.750 in.) diameter bar and the new method of roll forming, with the following results:

	Hobbed Shaft per 100	Rolled Shaft per 100
Material weight	91.5 lb.	73.7 lb.
Material utilisation	30.2%	38.4%
Material cost	£2 7 9	£1 18 6
Machining time	6.67 hrs.	1.26 hrs.
Total cost:	£16 11 0	£6 1 10

There is considerable scope for the application of work study to the design of sheet metal components; the majority of such parts are cut or pressed from strip or sheet material. Square, rectangular, or triangular shapes are therefore most economical, and invariably round or circular formations are most wasteful of material. Standardisation as far as possible with the same thickness of material in a range of components will enable the press tooling to accommodate the production of the smaller components from the waste material of the larger components. This should be done in the same tool, which results in no material or labour costs for the production of the smaller parts.

5. The Use of New Material and Processes

New materials and processes offer the biggest scope in the efficient utilisation of materials. As an example, a particular worm wheel was changed from the conventional machining methods to that of powdered metallurgy, with the result that the production operations were reduced from 10 to 6, material cost was reduced from £7 19s. 4d. to £3 4s. 0d. per 100, and the manufacturing time was reduced from 2.06 to .78 hours per 100.

Another example was that of actuator blades that were required at the comparatively small quantity of 40 per week. These were previously manufactured from bar material by conventional turning and milling operations. By using investment precision casting methods, the operations were reduced by nine and the machining operations reduced from $4\frac{1}{2}$ hours to $1\frac{3}{4}$ hours. The total cost was reduced from 9/8d. to 7/4d.

There are also the new materials and processes to give a hard face for protection against corrosion and abrasion which offer the designer new scope. This hard facing can be done by welding or metal spraying and the wear resisting surface often adds 5 to 10

times to the life of valves, chemical pumps, rock hammers, exhaust fans, etc. Engineering data and specifications of these hard face applications give the designer a new approach to many problems in the aircraft, rocket and jet engine development.

Russia and her satellite countries are coming into the field of the world machine tool market. It is interesting to see their new designs of drills, taps, reamers and milling cutters. A Russian technique has been developed for producing short flat reamers from high-speed steel machined blanks by radially forming the flutes, and the technique is also used for producing fluted lengths of high-speed steel which are then twisted to form blanks for twist drills. By extruding, rolling and twisting the high-speed steel blanks the manufacturing cost has been reduced by 30% because of better utilisation of material, and new design and manufacturing techniques. The performance of these Russian cutting tools is in the top grade.

In Poland, a new development of rolling and hot twisting is producing drill blanks in lengths of 3½ feet. These are cut into the suitable length and then by hot pressing are fitted into low carbon steel shanks. This technique reduces the consumption of high-speed steel by 40%. A new manufacturing method of making wood screws has been perfected by a Swiss engineer, and the machine is now being manufactured in Britain. The process saves up to 20% of material and there is no machining swarf. The screw is claimed to be 20% stronger by virtue of the favourable grain flow and work hardening.

When the newly developed materials and processes need to be introduced in order to achieve the objectives of efficient material utilisation, consistent quality, and lower production costs, mistakes and difficulties that the designer and draughtsman can experience are immense. It is here that the production engineer and the compilation of design reference sheets can be of great value. For example, it may be that the moulding process is required to be introduced and the designer or draughtsman does not appreciate the moulding technique with regard to mould cavity design and powder flow. Flash line location in relation to rib design, or flanges and undercuts in relation to side core and loose cores in the mould, or again the positioning of ejection bosses may not be appreciated.

To take another example, die casting may be introduced in which the process is not fully appreciated with regard to metal flow, draught on the die, distortion and contraction problems relative to variations in section thickness or die design problems relative to the location of bosses, fillet, radii and cored holes. Very often the production time and costs of a component are relative to the "down time" of moulds and dies, due to heavy maintenance.

Even with the most detailed calculations the sensible designer will always call for wall thicknesses of castings, forgings, die castings, mouldings, etc., on the safe side. It is only when the production samples have been produced from the tooling that a true test of the strength, weight and rigidity of the component can be made. This checking of the production component should always be carried out in order that the designer can mark up his detail drawings to indicate when wall thickness, ribbing, bosses, etc., can be reduced. Then when duplicate or replacement tooling is made it can be reviewed for improvement of material utilisation. On one particular die casting originally weighing 7 lb. it was possible to reduce the weight of aluminium by ½ lb. and this 7% saving represented £1,800 per year.

Recommendations on how to Proceed in Improving Material Utilisation

A few organisations are now training their designers, draughtsmen and production engineers in the application of work study and have already proved that major efficiency results. Prototype models are reviewed from the point of view of designing for ease of production, towards increasing productivity and lowering costs. Designs are considered from the efficient utilisation of materials and the economics of processes and tooling; in fact, it has been proven that where designs and drawings are not considered from a production point of view, expensive tooling and complicated processes can often needlessly be installed. Nothing is worse in industry than working on unnecessary procedures and operations to make them efficient. It is no good finding the right answers to the wrong questions.

No Design, Drawing Office or Production Engineering Department would be considered complete and, in fact, no senior designer or production engineer would be considered efficient without a number of reference books and data—Machinery Handbook, Mathematical Tables, Formulas, Area and Volumes, Strength of Materials, Laws of Mechanics, Measurement Conversions, etc. But it is equally important that those departments and technicians understand and accept the challenge of designing and production engineering for consistent quality and low manufacturing costs. It is important that each company carries out investigations and compiles company standards and policy on design and production engineering.

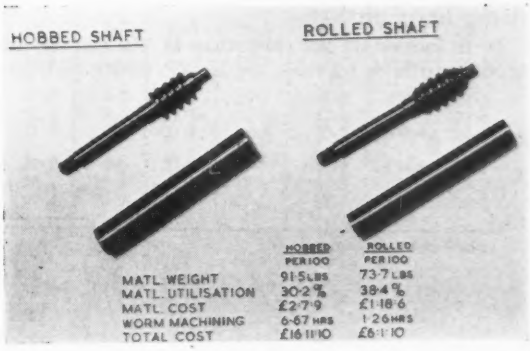


Fig. 5

To be able to design and detail to improve productivity, the first requirement is an analysis of your own company's product cost build-up. First in material, labour and overhead costs, and then a further breakdown of each, i.e., material cost per product in copper, aluminium, stainless steel, phosphor-bronze, etc. This information is best displayed in graph or chart form, in order to give a picture of comparisons for guidance to the designer, draughtsman and production engineer. But it is equally important that each company builds up reference sheets for information and guidance giving relative times, prices, costs, etc., of:

(1) material utilisation of the main materials used;
(2) the number of component parts of sub-assemblies and main assemblies;
(3) cost of materials used in the product with percentage comparisons;
(4) average machining time and costs for the main manufacturing operations;
(5) code and reference sheets of special component parts, such as brackets, spindles, shafts, bushes, feet, clamps, etc.;
(6) reference sheets of the standard selected materials that are stocked, i.e., in bar sizes, sheet sizes and gauges, etc.

In the Tool Design Office, these company standard and reference sheets should give comparisons of the loading, locating, unloading and clearing time of the alternative designs of jigs, tools, fixtures and gauges.

Conclusions

I have two letters from overseas that make comment on British design. One, from France, says: "At the Paris Fair many of the British domestic products exhibited were of robust and solid design, but they were really too heavy and cumbersome to use". From Holland, my correspondent states: "British household products are good mechanically, but how old-fashioned and heavy they look".

Gone are the days when catalogues and advertisements used the phrases "massive construction", "solid steel covers", "iron of heavy section", "robust heavy design"—all of which glorified sheer size and weight as representing quality. Invariably it will be found that it is lack of good detail design that results in clumsy heavy products.

It is interesting to read that in the raising of U.S.A. tariffs on bicycles, the bicycle under 36 lb. in weight suffers 11¼%, but the bicycle over 36 lb. pays 22½% duty.

These examples indicate that excess material in your product may well restrict your sales in the export market. On the other high costs of our products, i.e., overheads and indirect materials, it will be appreciated that all the five principles I have outlined for the efficient utilisation of materials also attack these costs. In reducing the number of component parts, the number of production processes, and the removal of waste material, an automatic reduction is applied to office records, stores stocks, purchasing and progressing, material handling, etc., simply by eliminating the need for them. In fact, the most positive way to reduce overheads is to reduce the number of component parts; for instance, if one part can do the job of an assembly of two, there will be one drawing instead of three, five blue prints instead of fifteen, etc.

It must be appreciated, however, that the very real problem connected with designing and production engineering for the efficient utilisation of materials is the fact that "It is so easy to make a thing complicated but very difficult to make it simple". Nevertheless, in one organisation that set out in earnest to improve its material utilisation, a 15% saving in material usage has been achieved. In another company, during a campaign entirely devoted to the problem of improving material utilisation, considerable and lasting savings were achieved. In a final analysis of the initiative and sectional activities responsible for these achievements, they were attributed as follows:

Production engineering	33%
Design of product	23%
Administration and offices	19%
Purchasing	18%
Suggestion scheme	7%
	100%

This indicates the scope that is available with the right approach to the efficient utilisation of material as an answer to our export and balance of payment problem.

What an excellent national example The Institution of Production Engineers has shown, in that this Welsh Regional Conference has chosen this challenge to British industry!

APPENDIX A

Imports of ores and metals

Monthly averages or calendar months

Thousand tons

	Nickel matte	Tin ore and concentrates	Zinc: Ore and concentrates	Zinc: Metal and alloys	Iron ore	Pig iron and sponge iron	Iron and steel scrap(1)	Crude and non-alloy semi-finished steel(2)	Steel non-alloy plates and sheets uncoated	Unwrought copper	Unwrought aluminium	Lead and lead alloys
1958	3·07	5·4	10·1	11·3	1,074·9	12·9	5·3	7·0	21·1	38·2	17·53	13·7
1959	2·80	5·1	12·7	14·6	1,112·5	8·4	0·2	0·2	22·0	36·4	20·86	15·0
1960	4·59	4·9	15·8	16·0	1,501·2	19·0	23·2	21·0	51·2	45·8	25·99	17·7
1960 January ...	5·56	4·4	5·5	24·7	1,353·1	6·6	5·9	0·5	40·9	44·2	28·13	13·1
February ...	3·03	5·1	8·7	17·6	1,293·4	8·5	17·7	1·9	49·0	39·8	38·33	13·1
March ...	4·95	4·8	26·8	19·8	1,398·8	7·2	18·6	7·5	52·3	43·5	31·39	16·1
April ...	4·12	3·1	20·4	15·1	1,304·0	5·6	14·9	5·6	52·5	42·6	26·75	23·0
May	4·41	4·5	15·1	13·0	1,483·3	23·6	10·3	16·9	64·8	58·1	27·11	13·1
June	5·24	6·6	29·1	15·8	1,643·3	23·0	6·4	16·5	98·9	45·3	29·62	15·5
July ...	3·65	4·9	27·3	12·6	1,660·3	25·4	25·3	41·9	98·7	55·6	16·50	20·1
August ...	8·64	4·3	13·5	11·4	1,819·9	43·0	57·1	42·0	68·1	49·8	21·24	20·9
September ...	1·52	4·8	14·4	14·0	1,659·0	35·6	40·5	34·9	42·5	45·5	23·94	16·4
October ...	5·88	4·9	11·9	12·4	1,592·0	13·4	25·9	17·6	22·0	45·2	19·86	19·6
November ...	1·65	5·9	9·5	18·7	1,618·6	19·1	2·9	34·4	17·0	43·8	28·09	20·0
December ...	6·49	5·3	7·5	17·1	1,305·6	17·0	54·8	34·8	15·5	38·6	20·67	22·0

(1) Excludes ships intended for breaking up.
(2) Ingots, blooms, billets, slabs, sheet bars and tinplate bars.

Source: Board of Trade

Other selected imports

Monthly averages or calendar months

	Rubber (1)	Timber: Non-coniferous (2)	Timber: Coniferous (3)	Timber: Plywood	Wood pulp	Paper and board: Newsprint	Paper and board: Other	Jute	Sheep's and lambs' wool(3)	Raw cotton (3)	Woven cotton fabrics, grey, unbleached	Petroleum: Crude and partly refined	Petroleum: Refined
	Thousand tons	Million cubic feet	Thousand standards	Thousand cu. metres	Thousand tons				Million lb.	Thousand tons	Million sq. yards	Million gallons	
1958	17·0	3·28	106·4	33·34	175·4	43·5	51·3	11·0	51·1	21·5	28·1	728·4	239·5
1959	17·0	3·47	121·7	40·94	185·4	42·4	57·9	12·5	58·6	22·5	38·4	846·9	276·9
1960	16·4	4·03	150·1	53·35	226·0	51·3	67·1	11·5	49·9	22·6	49·8	968·9	293·6
1960 January ...	14·5	2·98	88·3	56·00	217·7	43·8	70·5	17·5	75·6	25·1	43·2	842·0	319·4
February ...	18·1	3·50	67·0	50·07	233·7	51·3	55·5	23·5	46·8	34·7	52·2	1,015·7	376·5
March ...	25·4	4·71	75·8	53·10	214·1	35·7	73·1	16·3	56·9	26·4	52·7	910·1	374·7
April ...	16·7	3·91	70·5	57·43	197·5	49·6	66·2	5·2	62·3	26·5	45·3	953·3	302·1
May ...	14·2	3·73	139·2	56·34	247·4	64·0	71·0	6·2	60·9	20·4	50·7	918·1	277·5
June ...	20·4	4·10	201·5	67·17	242·3	55·1	59·9	6·6	44·0	18·7	47·2	1,055·2	280·3
July ...	18·6	4·67	213·9	48·17	182·2	52·6	67·8	6·0	57·1	26·3	45·8	905·0	251·1
August ...	7·7	4·67	244·6	47·86	228·4	50·0	58·3	9·4	37·1	26·6	53·6	1,108·0	273·6
September	6·5	4·29	189·9	45·87	235·7	46·8	71·8	3·2	27·7	8·4	50·5	1,005·6	227·9
October ...	15·5	3·95	179·3	45·45	215·1	61·1	67·5	4·5	30·2	11·7	49·9	1,034·8	200·6
November	19·6	3·92	173·9	56·05	268·7	60·3	74·2	19·9	48·7	19·6	54·3	1,125·9	339·3
December...	21·0	4·10	154·5	61·22	237·3	50·1	69·2	20·0	56·1	27·2	52·1	942·1	326·8

Source : Board of Trade

(Appendix B overleaf)

APPENDIX B

A RECOMMENDED PROGRAMME OF COMPANY PROCEDURE TO IMPROVE MANUFACTURING AND OVERHEAD COSTS BY THE EFFICIENT UTILISATION OF MATERIALS

1. It is good management to stage periodic campaigns to allow for :—
   (a) leadership to raise the standard of expectancy;
   (b) targets for higher achievement to be set and actual results recorded;
   (c) acknowledgement, appreciation, and acceptance of new records to be acclaimed.
2. The campaign must be positive (e.g., it must never be dubbed "Cost Reduction", "Conservation of Materials—Material Saving, etc.", for people like to be associated with positive success and not negative austerity).
3. Everyone in the organisation—Works Committee, Joint Production Committees, Suggestion Schemes, etc., will desire to contribute or be associated with improved material utilisation (i.e., there is no scapegoat, redundancy, or grounds for suspicion).
4. Improved material utilisation in the majority of cases costs very little to implement; the savings can be almost immediate, they are definable, positive, and can often be continuous (i.e., they are not tied up with overheads or intangibles).
5. Each departmental chief should be given the challenge to review the materials, methods, and procedures in his own department, and if these have remained unchanged for more than five years there must be a better way.
6. Positive ways for improving that most wasteful of all materials, i.e., paperwork, are :—
   (a) amalgamation of departments and functions;
   (b) streamlining and simplifying the necessary procedures;
   (c) avoiding duplication, "defence" paperwork, and record keeping.
7. Design engineers must be made aware of relative material costs, the percentage of material utilisation of the products they design, and the alternative production techniques.
8. Detail draughtsmen should be provided with reference sheets dealing with efficient material utilisation. They should be informed on the standard sizes, shapes, and descriptions of materials (i.e., sheet metal parts of triangular, rectangular, or square shape). The most wasteful material tool can be the draughtsman's compass!
9. Production Engineers responsible for process planning should state on the Operation Process Sheet the gross material to be purchased, the nett quantity of material resulting in the finished component, and the percentage of material utilisation. The final instructions on the Operation Process Sheet should state how the wasted material is to be dealt with. Duplicate or replacement tooling should be reviewed for improved material utilisation (e.g., a reduction in wall thickness, ribbing, bosses, etc., in die castings and mouldings).
10. Production Control Supervision must ensure that excess material usage is investigated, recorded, and corrected.
11. Purchasing Officers and Goods Inwards Inspectors should check indirect material requisitions and receipts in order to ensure that the material is being purchased and delivered in the most economic condition for the application involved (e.g., soldering flux may cost more per gallon in one-pint containers—but that could be the most economical condition).
12. Cost accountants should ensure that their standard costs give a summary of the value of material utilisation. Budgeted overhead costs should detail indirect material expenditures. A material variance value should be included in the monthly cost statements. Redundant and excess material stocks, as indicated from stock audits and stocktaking, must be reported to Factory Manager.

Production Engineering in Peru — conclusion

Arising from discussions relating to the training of production engineers, Ing Succar is most anxious that Peru should follow the pattern of Britain, and I left with him particulars relating to courses at the Birmingham College of Advanced Technology and also the Department of Engineering at Birmingham University.

I found enthusiastic audiences everywhere, not only at the University, but at the various luncheon and evening lectures I was invited to give. There is a real and urgent need for technicians to train executives in production engineering methods, so that the masses of cheap labour which are available may be used most economically.

PRODUCTION ENGINEERING TRAINING IN PERU

A report by R. N. MARLAND, B.Sc.,
A.M.I.Mech.E., M.I.Prod.E.

Arising from a request by the British Council, Mr. Marland spent six weeks in Peru lecturing on Time and Method Study. In this report he has recorded some impressions of his visit.

HAVING semi-retired at the beginning of this year, I was first introduced to the idea of visiting Peru by Mr. Woodford, Secretary to the Institution, following a request from The British Council for a production engineer to give a series of lectures based on Time and Method Study to be presented at the Engineering University of Lima.

This request resulted from the visit made last year by Sir Thomas Hutton, also on behalf of The British Council, who in his report emphasised the urgent need of training in subjects related to Production Engineering. He was also instrumental in the development of CENIP (Centro Nacional de Acción para el Incremento de la Productividad), in conjunction with Ing. Succar (Dean of the Faculty of Industrial Engineering) at the Universidad Nacional de Ingenieria at Lima.

I accepted the invitation conditional upon the visit not extending more than six weeks, and accordingly flew via New York on 25th March and returned on 6th May.

In conjunction with Ing. Succar, two series of lectures were arranged, each of nine two-hour sessions; one series being given to the professors from the various faculties and executives from industry, and the other series to final year students. Between 30 and 40 attended each group, and the subjects comprised Time and Method Study with applications, job evaluation with examples, production planning and control, materials handling, improved material utilisation, etc. I was greatly assisted by films of the British Productivity Council, some of which had been sent out by Sir Thomas Hutton and others which I arranged to be sent.

Peru has an area of 506,000 square miles, with a population in 1958 of 10,369,000, of whom about 50% are illiterate Andean Indians living a bare subsistence existence as agriculturists or unskilled workers. Only about 3,700,000 are gainfully employed, being distributed :—

Agriculture and Livestock ...	60%
Manufacturing	19%
Commerce	5%
Services	4%
Mining	2%
Others	10%

At present, the wealth of the country lies mainly in the vast irrigated sugar and cotton estates on the coast, the oil fields in the north, the mines producing zinc, lead, copper and iron ore, and the fish meal industry.

I was privileged to visit a number of factories and installations. At the Fabrica de Tedjidos "La Union" Ltda, for instance, I saw some of the most modern textile machinery from Britain, America, Switzerland and Germany.

At the Industrias Reunidas, on the other hand, making 45% of Peru's requirements of holloware as well as 10,000 petrol cans per day, and about to embark on the manufacture of refrigerators, I saw a spacious factory very much lacking in efficient production planning and control, poor materials handling, machine production very much out of balance. In fact, I estimated that twice the output could have been produced in half the area, and yet the firm is contemplating the erection of another factory.

Politically there is evidence of Communist infiltration or "leftish" tendencies, especially among the students. America is very much concerned and Ing Succar has recently visited Washington by invitation of President Kennedy to consider what assistance can be given to improve the standards of higher education. Nevertheless, the Peruvians generally are very pro-British and would welcome even closer ties with this country.

It is possible that Sir Vincent Tewson may, at the invitation of The British Council, pay a brief visit later this year. The object of his visit will be to discuss with both trades unions and employers the machinery operating in this country for the avoidance of disputes, as well as to endeavour to create a better understanding between the two sides.

One of my terms of reference was to select suitable graduates for further training in the United Kingdom and I have suggested the names of three for this year and a further two for next year. I have proposed that each of these persons should receive scholarships, possibly from F.B.I., to enable them to spend one or two years on Sandwich Courses in Production Engineering.

(concluded on facing page)

B.C.A.C. Conference on "Automation – Men and Money"

THE Conference on "Automation—Men and Money", sponsored by eight of BCAC's member institutions,* was opened at Harrogate on June 27th by the Minister for Science, Lord Hailsham, and was attended by nearly 300 delegates. The following are some of the points made by the Conference Chairman, Sir Walter Puckey, Past President, Institution of Production Engineers, in his summing up.

Lord Hailsham had told us in clear terms that our real challenge was to safeguard Britain's international position. "We shall," he had said, "be successfully competed against and beaten in one field after another unless we exploit our brains and forethought". This, Sir Walter interpreted as achieving the condition that when a competitor arrives somewhere with a new idea, he should meet a British salesman coming out with a smile on his face, and an order in his pocket.

One of the significant features of automation would be its likely impact upon our social as well as our industrial lives. The first years of automation largely followed in the trail of mechanisation, which invaded industrial life on and around the factory floor. But the future of automation would be equally in the sphere of office mechanisation and in social activities such as banking, credit systems, retail merchandising and, of course, in the further development of home mechanisation.

automation and redundancy

Today there is a healthier understanding of man's working and social obligations and requirements than a few years ago. A constantly asked question was whether automation will bring redundancy. In planning this Conference they had sought for evidence of automation redundancy, and found none. He believed that the attention paid to this matter since automation was introduced here has forewarned and forearmed us. "But the present industrial labour scene is too delicately poised for us to be complacent about the effects of any significant technological or economic change, particularly when it is remembered that the full effect of automation is not yet here."

"In the field of education, the pillar of high grade College education is being erected to stand firmly and proudly by the side of the older University edifice. Our Colleges, largely through the Dip. Tech. programme, are establishing new and widespread contacts with industry, and will provide industry soon with thousands of honours graduate technologists, who are particularly suited to the application of automation and other modern techniques." The Colleges will also, he predicted, become centres of applied research, especially valuable to small firms.

* including The Institution of Production Engineers.

importance of quick decisions

Sir Walter referred to the sincerity of all who approached the subject of conditions, compensation, joint consultation and the older worker. If sincerity were enough there would be no problem. Automation had not made a real impact yet on industry, and these problems would become more serious later. He believed in consultation at the earliest and frankest stage, but even this, though important, was not enough. Quicker decision is more than ever vital in these days, where time is often our only advantage over competitors.

He thought that capital formation was not a major problem today, despite the heavy capital demands of automation. One old problem of capital utilisation was becoming intensified by automation. How financially desirable, and how socially undesirable is shift work, which will use capital goods more intensively? In U.S.A. most computers are on shift work. Will we in Britain face this, and how much will it complicate payment and other problems in the staff field? We must find the answer soon.

JOINT STUDY GROUP FOR ROAD TRANSPORT MATERIALS HANDLING

AFTER some months of meetings The Institute of Materials Handling, The Institution of Production Engineers and The Institute of Road Transport Engineers have prepared a full length report on the needs of materials handling for road transport.

The document is fully comprehensive, but the main points may be summarised as the recommendations of the Joint Committee. These are divided under two headings and are :—

(a) **The Construction of Commercial Vehicle Platforms to facilitate the handling of materials by mechanical means.**

1. That the number and spacing of cross-bearers and the strength of the floors in flat platform vehicles be such as to render those floors susceptible to withstand a one-ton load carried on a hand or powered pallet truck. This would involve a maximum loading of 1,650 lb. per wheel, giving rise to a potential load of (1,650 x 2) lb. between any two cross-bearers, and with any one plank laid longitudinally accepting a wheel loading of 1,650 lb.

2. That the surface hardness of vehicle platform floors be such as to reduce rolling resistance to the minimum whilst affording a high degree of durability and non-slip potentiality, having regard to the safety of persons walking on these floors.
3. That, in connection with the majority of normal-user vehicles, 48 in. is regarded as being a satisfactory standard loading height.
4. That wherever practicable 86 in. shall be the minimum width between chock raves, to accommodate pallet sizes.
5. That the maximum height of side raves on flat platform vehicles be 1½ in.
6. That the bracing of head (loading) boards be such as not to interfere with the handling of the foremost pallets over the side of an open vehicle.
7. That the design of vehicle bodies be such that drop sides will hinge away flush to the periphery of the vehicle, wherever chassis design renders this practicable.

(b) **Other recommendations**

1. In the case of box vans, rear openings should be of maximum width, and the width of side pillars should be kept to the minimum, to facilitate mechanical loading techniques.
2. Recommendations 1, 2 and 3 under paragraph (a) above apply equally to closed vehicles such as box vans.

The report, in addition to a fuller discussion of these points and reasons for these recommendations, gives the bases on which the recommendations are made and a table of design data for the strengths of various timbers.

The report is to be printed in full and copies will be available from any of the three Associations, at a nominal charge.

DIARY FOR 1961-1962

1961

OCTOBER 17 ... ... **The 1961 Sir Alfred Herbert Paper, London.**
Speaker: **Mr. David Donne,** Charterhouse Industrial Development Co.
Subject: **"Finance in Industrial Growth"** (see Journal Supplement)

NOVEMBER 1 ... ... **Annual Dinner, Dorchester Hotel, London.**
Principal Guest: **The Rt. Hon. the Viscount Chandos, P.C., D.S.O., M.C.**
(see Journal Supplement)

NOVEMBER 3-4 ... ... **Materials Handling Convention, London.**
Theme: **"Profit by Handling"** (see Journal Supplement)

1962

APRIL 5-7 ... ... **Aircraft Production Conference, College of Aeronautics, Cranfield.**
Theme: **"Building Aircraft for the Competitive World Market"**

ELECTIONS AND TRANSFERS

approved at the Meeting of the Council of the Institution

27th July, 1961

ADELAIDE SECTION

As Members
A. M. Freestun; A. K. Claridge.
As Associate
A. B. Jack.
As Graduate
A. D. Grant.

BANGALORE SECTION

As Members
P. S. Banerjee; R. Natarajan.
As Associate Member
R. Yogeshwar.
As Students
R. R. D. Kumar; N. Neelakanta; J. Varghese; O. K. Wahie.
Transfer
From Associate Members to Members
D. P. Basu; A. F. Eugene.

BIRMINGHAM SECTION

As Associate Members
A. White; F. R. Forster.
As Graduates
R. B. Kay; P. A. Taylor; J. A. Allcott.
As Students
C. E. Adenegan; P. H. Turner; N. N. Desai; B. W. Jones.
Transfers
From Associate Members to Members
H. A. Whittall; M. F. Jones; J. G. Lowe.
From Graduates to Associate Members
R. Hill; P. W. Thorne; R. B. Beard; K. W. Morris; C. S. Phillips; J. S. Williams.
From Students to Graduates
A. J. Miles; R. C. Price; J. W. Bragginton; K. W. Malkin.

BOMBAY SECTION

As Graduate
S. P. Narayanan Nayar.
As Students
N. Srinath; R. V. Joshi; L. T. Sabhachandani; N. N. Kale; S. K. Handa.

CALCUTTA SECTION

As Associate
B. K. Chandra.
As Students
N. V. Rajagopalan; A. Mookherjee; S. K. Gaur; G. P. Khurana; A. N. Chatterjee.
Transfer
From Graduate to Associate Member
S. Sundaram.

CANADA SECTION

As Graduate
J. M. Magro.
As Student
W. A. Milne.
Transfers
From Associate Member to Member
S. W. W. Carroll.
From Graduate to Associate Member
K. H. Jones.

CARDIFF SECTION

As Associate Members
G. Vlismas; D. H. M. Williams; A. D. Murray.
As Students
A. T. Exton; A. C. Vaterlaws.
Transfer
From Graduate to Associate Member
W. E. Jenkins.

CORNWALL SECTION

As Member
F. A. Houghton.

COVENTRY SECTION

As Graduates
D. Edwards; P. C. Woolnough.
As Students
R. P. Walduck; P. H. Edwards.
Transfers
From Associate Member to Member
K. C. Bairstow.
From Graduates to Associate Members
K. J. Miller; W. S. Haley; G. E. Mead; D. Graham.
From Students to Graduates
J. S. Robinson; A. Fisher.

DERBY SECTION

As Member
F. W. W. Morley.
As Graduate
G. F. R. Trueman.
Transfers
From Graduate to Associate Member
D. F. Halewood.
From Student to Graduate
A. L. Graham-Bryce.

DUNDEE SECTION

As Graduate
D. T. Foote.
As Student
D. M. Whitton.

EDINBURGH SECTION

As Student
I. T. Robertson.

GLASGOW SECTION

As Associate Member
A. I. M. Macmillan.
As Graduate
L. E. T. O. McMillan.
From Associate Members to Members
W. H. Marley; J. R. Young; R. A. MacLeod.

GLOUCESTER SECTION

As Graduate
D. E. Merrett.
As Student
D. F. Grigg.

IPSWICH & COLCHESTER SECTION

As Graduate
G. Baker.

LEEDS SECTION

As Student
R. Hearn.

LEICESTER SECTION

As Graduate
B. A. Fletcher.
As Students
C. P. J. Foster; R. J. Coombes.
Transfers
From Graduate to Associate Member
J. A. Prettyman.
From Students to Graduates
A. Roberts; D. R. Coleman.

LIVERPOOL SECTION

As Graduates
A. J. Rushton; E. R. Irwin; J. L. Wright.
As Students
F. Tromp; R. N. Fitzpatrick.
Transfer
From Graduate to Associate Member
J. R. Jones.

LONDON SECTION

As Members
H. J. Sephton; D. L. Nicolson; R. Isherwood-Crook.
As Associate Members
W. J. King; W. A. Long.
As Graduates
W. S. Horwood; F. E. Mepham; J. B. Doe; B. A. Haynes; J. E. Pearce.
As Students
M. A. Waters; J. A. McIlwraith; T. E. Roberts; B. R. C. Froud.
Transfers
From Associate Members to Members
T. A. Johns; P. H. J. Johnson.
From Graduates to Associate Members
J. A. Worthington; T. D. Cleary; A. R. Fryatt; R. A. Draves; J. H. Flack.
From Students to Graduates
D. R. Snipper; A. G. Peters; K. C. Hulford; A. G. Peach.

LUTON SECTION

As Associate
B. Armstrong.
As Graduates
V. A. T. Brown; V. J. Bird; P. G. Rowe.
Transfers
From Associate Member to Member
C. E. Cumins.
From Graduate to Associate Member
R. A. King.

MANCHESTER SECTION

As Member
L. J. Tolley.
As Graduates
J. S. Smith; S. T. Cowan.
As Students
A. K. Bhattacharjya; E. Drew.
Transfers
From Associate Members to Members
R. S. Clark; M. P. Rubert.
From Students to Graduates
D. Norris; M. Norris; R. Sharples.

MELBOURNE SECTION

As Associate Member
D. G. Ritchie.
As Graduates
L. E. Morris; F. R. Fradd; K. G. Johnston; N. Lesh.
As Students
D. A. Hall; B. A. Imison; V. G. Cisera; L. Lyon; R. G. Clarke; A. A. Beatson (Article 19); J. E. Sexton; P. C Phillips.
Transfer
From Student to Graduate
R. B. Hodges.

NEWCASTLE-UPON-TYNE SECTION

As Associate
E. R. C. Farmer.
As Graduates
D. M. Nicod; J. Little; D. Jones; W. Graham.

NOTTINGHAM SECTION

As Graduate
A. E. Weldon.
As Student
J. M. Smith.

OXFORD SECTION

As Student
J. G. Hermann.
Transfer
From Student to Graduate
R. J. Houston.

PETERBOROUGH SECTION

Transfers
From Associate Member to Member
E. Steele.
From Graduate to Associate Member
D. S. Townsend.

PRESTON SECTION

As Graduate
N. C. Naylor.
Transfers
From Associate Member to Member
R. J. Evans.
From Student to Graduate
F. Gee.

READING SECTION

As Member
D. Randolph.
As Associate Member
D. E. Welch.
As Student
C. R. L. Stevens.
Transfers
From Associate Member to Member
R. G. Winton.
From Graduates to Associate Members
P. H. Reynolds; J. A. Murrell.

ROCHESTER SECTION

As Students
M. C. Harwar; R. F. Millen.

SHEFFIELD SECTION

As Member
R. S. Bruce.
As Graduate
B. Wilkes.
As Student
M. J. Wroe.
Transfer
From Graduate to Associate Member
N. Vollans.

SHREWSBURY SECTION

As Associate Member
R. W. Butler.
Transfers
From Students to Graduates
J. A. Davies; J. M. Dovey.

STOKE-ON-TRENT SECTION

As Student
A. S. Cornes.
Transfer
From Graduate to Associate Member
L. W. Carlisle.

SOUTHAMPTON SECTION

As Associate Members
N. Lockwood; W. T. Jackson.
As Graduates
D. K. W. Deadman; D. J. C. Bernard
As Affiliated Firm
Leicester, Lovell & Co. Ltd.
Transfers
From Students to Graduates
M. H. Espezel; J. E. Thompson.

SOUTH AFRICA SECTION

As Associate Member
D. Hindle.
As Associate
J. L. D. Nicholson.
As Graduate
J. G. Robson.
As Student
C. T. Hutchinson.
Transfers
From Associate Member to Member
E. H. Dallas.
From Graduate to Associate Member
D. I. Gray.

SOUTH ESSEX SECTION

As Graduates
C. W. Wager; B. R. Ganiford; J. C. Snook.
As Students
R. J. Froud; W. I. Hall; R. C. Baker; D. F. Clift; J. G. Ewen.
Transfers
From Student to Graduate
R. C. Dicks.

SWANSEA SECTION

As Student
M. E. Russ.
As Affiliated Firm
The Tawe Tool Co. Ltd.

SYDNEY SECTION

As Associate Member
F. R. W. Amos.
As Graduate
W. H. Thompson.
As Students
R. D. W. Gow; A. T. Redman.
As Affiliated Firm
Castrol Limited.

TEES-SIDE SECTION

Transfers
From Associate Member to Member
A. Smith.
From Graduate to Associate Member
C. F. Bethell.

WESTERN SECTION

As Graduate
K. G. Smith.
As Student
G. J. Brixton.
Transfers
From Students to Graduates
E. R. H. Damagnez; J. A. Hulin.

WOLVERHAMPTON SECTION

As Associate Member
E. B. Harper.
As Graduates
M. D. Richardson; B. Butler; W. R. Corfield; D. B. Griffiths.
Transfers
From Associate Member to Member
D. G. Wiley.
From Graduates to Associate Members
E. C. G. Albrecht; B. H. Porter; W. H. Baugh; D. Parkes.
From Students to Graduates
T. E. Beedle; G. G. Davies; D. J. Howell; B. Picton; T. Chadwick.

WORCESTER SECTION

As Graduate
T. G. Treadgold.
Transfer
From Graduate to Associate Member
A. Etchells.

NO SECTION

As Associate Members
P. Petropoulos; M. A. Sheikh.
As Associate
C. J. Gorvin.
As Graduate
S. K. Lam.
As Students
A. Kumar; Z. A. Abbasi.
Transfers
From Graduate to Associate Member
B. Butterfield.
From Student to Graduate
W. A. Quansah.

THE STANDING COMMITEES, 1961/62

The following members have been elected to serve on the Institution's Standing Committees for the year 1961 - 1962 :

Finance and General Purposes Committee

The Principal Officers:
The President: Mr. Harold Burke.
The Vice-President: Mr. R. Ratcliffe, C.B.
The Chairman of Council: Mr. R. H. S. Turner.
The Vice-Chairman of Council: Mr. A. L. Stuchbery.
The Immediate Past Chairman of Council: Mr. H. W. Bowen, O.B.E.

Elected Members:
R. S. Brown
E. Percy Edwards
H. G. Gregory
R. E. Leakey
G. Ronald Pryor
G. A. J. Witton

The Chairmen of all Standing Committees — Editorial, Education, Hazleton Memorial Library, Membership, Papers, Research and Technical, and Standards — are ex-officio members of the Finance and General Purposes Committee.

Education Committee

The Principal Officers:
W. G. Ainslie
R. L. Aston
Dr. E. N. Corlett
C. E. Darlington
J. A. W. Deboo
R. Dent
K. J. Hume
C. F. Hurst
Dr. T. U. Matthew
M. G. Page
J. H. Perkins
O. F. Rendell
F. Taylor
C. A. Whitford
T. B. Worth

Membership Committee

The Principal Officers:
A. Betts Brown
W. M. Buchan
F. S. Chappell
G. H. Crump
R. Dent
E. Percy Edwards
E. G. Kinch
H. W. Lawton
T. F. Newton
R. D. Owen
L. J. Service
H. Spencer Smith
J. A. W. Styles
K. E. Taylor
R. Wheeler

Editorial Committee

The Principal Officers:
John M. Brice
Dr. G. S. Brosan
Dr. E. N. Corlett
Dr. S. Eilon
J. L. Gwyther
H. Peter Jost
J. C. Z. Martin
R. E. Mills
M. J. Sargeaunt
B. E. Stokes

Papers Committee

The Principal Officers:
John M. Brice
Dr. G. S. Brosan
F. C. Cooke
A. A. J. Francis
L. Landon Goodman
J. A. Grainger
A. J. Lawrance
J. C. Z. Martin
R. E. Mills
I. S. Morton
G. Wittenberg

Research and Technical Committee

The Principal Officers:
L. W. Bailey
C. T. Butler
J. H. Devonald
Prof. N. A. Dudley
F. G. S. English
R. M. Evans
D. N. Everton
J. L. Gwyther
H. W. Mander
K. H. Matthews
S. G. E. Nash
A. P. Oppenheimer
J. R. Thompson
P. Warburton
E. A. Wootton

Standards Committee

The Principal Officers:
B. W. Charman
D. B. Ebsworth
P. C. T. Goodrum
J. Harris
R. E. Mills
L. H. Milsom
J. D. Morrison
B. A. J. Rule
T. A. C. Sparling
H. Stafford
E. Steele
J. H. Winskill
W. E. Wright

Hazleton Memorial Library Committee

The Principal Officers:
J. Aikman
L. W. Bailey
J. Isaacs
H. L. Madeley
R. V. Rider
M. J. Sargeaunt
The Lord Sempill, A.F.C.
F. B. Willmott

PAST PRESIDENT HONOURED

At a special meeting of the Council of the Institution, held in the House of Lords on 15th June last, **Mr. G. Ronald Pryor,** the Retiring President, was unanimously elected an Honorary Member of the Institution.

Mr. Pryor was presented with a special certificate of Honorary Membership contained in a silver frame on which is inscribed the signatures of serving members of the Council and of the executive Headquarters staff.

There are now eight Honorary Members of the Institution. They are, in addition to Mr. Pryor, Mr. J. Finlay, M.B.E.; Mr. E. W. Hancock, O.B.E.; Viscount Nuffield, G.B.E.; Mr. J. D. Scaife; Lord Sempill, A.F.C.; Dr. H. Schofield, C.B.E.; and Mr. H. E. Honer.

The Institution of Production Engineers.

Whereas:—

George Ronald Pryor

was elected a

Member of the Institution of Production Engineers

on 9th June, 1937

And whereas he subsequently served on the Sheffield Section Committee and became President of the Sheffield Section and served on the [illegible] Regional Committee and became Chairman of the [illegible] Region.

And whereas he was elected to the Council of the Institution in 1945 and served continuously as a member of the Council holding office as Vice-Chairman 1952/53 and 1953/54 and Chairman 1954/55 and 1955/56 and was then elected a Vice-President of the Institution 1957/58 and 1958/59 and served as President of the Institution 1959/60 and 1960/61.

And whereas he has served for many years on the Finance and General Purposes Committee and has given service to the Institution and to the Profession in numerous other ways.

THEN BE IT KNOWN

that at a Special Meeting of the Council held on June 15th 1961 he was unanimously and with acclamation elected an

HONORARY MEMBER

AUSTRALIAN PRESIDENT OPENS MACHINE TOOL LABORATORY

On 30th May, 1961, an event of great significance to Australian industry took place when **Mr. Ian McLennan,** *C.B.E.,* President of the Institution's Australian Council, and Chief General Manager of Broken Hill Proprietary Company, Ltd., opened the O. E. Nilsson Production Engineering Machine Tool Laboratory at the Swinburne Technical College, Melbourne.

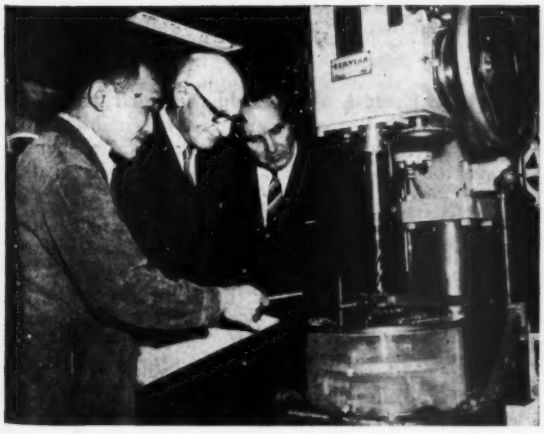
Production Engineering courses following the Institution's syllabus have been taught for some years at a number of technical colleges in Australia, but training of students in advanced production techniques has always been limited by the fact that all practical work has had to be carried out in machine shops set up primarily for the training of trade staff.

Now for the first time an Australian technical college has set up an advanced Machine Tool Laboratory well equipped for investigations into cutting and forming processes, and already industry in Melbourne has started setting problems for the advanced students working in the laboratory. Such problems as the relative performance and efficiency of various types of milling cutters, the effects of various methods of drill sharpening, the gain in quality to be achieved when centreless ground stock is used in an automatic, tool design for a particularly difficult material, and the effects of lubricants on the cutting process are typical.

Assistance was given to the Swinburne Technical College by members of the Committee of the Institution's Melbourne Section, who advised on equipment and machines. The Institution's recognition of the courses conducted at Swinburne Technical College and the Australian members' support of the laboratory project is appropriately acknowledged by the invitation to Mr. McLennan to perform the opening ceremony.

Mr. Ian McLennan (above) performing the opening ceremony. On the left is Mr. A. McDonell, Director of Education, and Mr. R. G. Parsons, President of the Swinburne Technical Council, is on the right.

An Asian student in Australia under the Colombo Plan, explains the drill dynamometer to Mr. O. E. Nilsson (centre), Chief Inspector of Victorian Technical Schools, in whose honour the new Laboratory is named, and Mr. McLennan.



INDIAN PRODUCTIVITY TEAM

Mr. R. A. P. Misra, M.I.Prod.E., Past Chairman of the Institution's Bombay Section, acted as Secretary to the Indian Productivity Team on the Machine Building Industry, which recently visited the Soviet Union and Czechoslovakia. The visit was sponsored by the National Productivity Council of India under aid from the Governments of U.S.S.R. and Czechoslovakia. The leader of the team was **Mr. J. V. Patel,** also a Past Chairman of the Bombay Section.

Mr. Misra is Managing Director of the Indian Furnace Company Private Ltd., Bombay.

S.E. REGION GRADUATE PRIZE

The Committee of the South Eastern Region of the Institution have again decided to award a prize for the best Paper submitted by a Student or Graduate of the Region on any subject within the field of production engineering. The prize consists of £25 and a certificate as a permanent memento. The winner, and other candidates whose entries reach a certain standard, will be invited to attend the Regional Dinner-Dance, where the presentation will be made.

Full details of how to enter for the award are given in the Supplement to this Journal.

LORD HALSBURY'S NEW OFFICE

The. Rt. Hon. the Earl of Halsbury, President of the Institution from 1957-1959, has been elected President of the Machine Tool Industry Research Association.

Lord Halsbury is, of course, well known for his work on the application of scientific research, and has many connections with the machine tool industry. From 1949-1959 he was the first Managing Director of the National Research Development Corporation, and in this capacity was associated with machine tool research at the Manchester College of Science and Technology. Among his many offices, he is a member of the Court of Governors of that College and a Governor of the B.B.C.

NEWS OF MEMBERS

Wing Commander J. M. Aiton, D.L., Member, has been appointed Chairman of the F.B.I. North Midland Regional Council. He is Chairman and Managing Director of Aiton & Co. Ltd., Derby, and Director of Aiton Africa (Pty.) Ltd., Aiton Australia Pty. Ltd., and Thermap S.A. Paris.

Mr. David H. Bramley, Member, has been appointed Production Director of Geo. Salter & Co. Ltd. Mr Bramley joined the Salter Board in an advisory capacity in 1958, since when he has been also responsible for the management training service of Urwick Orr & Partners, management consultants. He is now relinquishing this position to allow him to concentrate on Salter production. He is a founder member of the B.I.M., and was a member of the first special Committee set up by the Ministry of Labour in 1954 to make recommendations on supervisory management training in British industry.

Mr. B. C. Harrison, Member, has been appointed Deputy Managing Director of Alfred Herbert Ltd. Mr. Harrison, who was an apprentice with the Company, has been a member of the Board since 1947, and was appointed Works Director in that year. In 1955 he became Director of Design. He is a Corresponding Member of the Institution's Papers Committee.

Mr. Harry Dixon, Member, Chief Inspector at Hoover (Washing Machines) Limited, Pentrebach, recently completed 25 years' service with the Company. In token of this long service he was presented with a gold watch by Hoover Ltd.'s Comptroller. Mr. Dixon is a past Chairman of the Wales Region and the Cardiff Section of the Institution.

Mr. R. M. Evans, Member, has been appointed Managing Director of The Imperial Typewriter Co., Leicester. Mr Evans, who joined the Company in 1928, became a Director in 1934. He was appointed Assistant Managing Director in 1956, and Deputy Chairman in 1959, a position he still holds. He is a past Chairman and Vice-Chairman of the Institution's Leicester Section and has also served on the North Midlands Regional Committee. He is at present Chairman of the Research and Technical Committee.

Mr. F. J. Everest, Member, has resigned from the Board of David Brown Industries Ltd., in order to take up an appointment as Director and General Manager of Stein Atkinson Vickers Hydraulics Ltd.

Mr. K. Farnell, Member, Principal of the Cornwall Technical College, has been made a Doctor of Philosophy, in the Faculty of Engineering, University of London. He is Chairman of the Institution's Cornwall Section.

Mr. J. G. Lloyd, Member, has recently been appointed Controller of Forward Development of the Vickers Group.

Mr. C. Luby, Member, has relinquished his position as Joint Managing Director of Dowty-Rotol Ltd., and has accepted an invitation to join the Board of the Bristol Aeroplane Company. Mr. Luby is a past Chairman of the Institution's Canadian Section.

Mr. C. Phillips, Member, has been appointed Joint Managing Director of Redman Tools and Products Ltd.

Mr. S. P. Woodley, M.B.E., Member, has been appointed a Director and Assistant Managing Director (Southern Works) of the Vickers Group, in addition to his existing duties.

Mr. B. J. Andrews, Associate Member, has relinquished his position as Chief Production Engineer of Multitone Electric Co. Ltd., and has taken up an appointment as Works Manager with Electronic Associates Ltd., Sussex.

Mr. W. R. Collier, Associate Member, of the Lincoln Section, has been awarded the M.B.E. for his work in the naval section of Rose Brothers, Gainsborough.

Mr. Collier joined the Admiralty Section of the firm in 1952, and has since specialised in design and development of gunnery systems. More recently he has been engaged on the Seacat guided weapons project.

Mr. T. F. Hurst, Associate Member, formerly Group Work Study Engineer, has been appointed Superintendent of N.B. Department, British Timken Ltd.

Mr. L. K. Lord, Associate Member, General Manager of Arthur Scrivener Limited since 1955, has recently been appointed Director and General Manager of the Company. Mr. Lord, who is a Freeman of Coventry, is a past winner of the Institution's Hutchinson Memorial Award.

Mr. T. Garne, Associate Member, has relinquished his position with Wickman Limited, Coventry, to take up an appointment as Manager, General Division, with High Precision Equipment Limited, Bletchley, Bucks.

Mr. V. A. Hollyoak, Associate Member, has recently been appointed Chief Production Engineer of J. G. Statter & Co. Ltd, and its subsidiary, Minerva Mouldings Ltd., in the Metal Industries Group.

Mr. W. P. Mirtle, Associate Member, has been promoted to Deputy Manager, Madras Works of the English Electric Company of India (Private) Ltd. He was formerly Superintendent Production Control, English Electric Co. Ltd., Stafford.

Mr. D. R. Lawson, Associate Member, previously a Methods Engineer with Smiths Motor Accessories, Cricklewood, is now Assistant Works Manager of Portland Plastics Ltd., Hythe, Kent, a subsidiary of the Smiths Group. A former member of the London Graduate Section Committee and the Hazleton Memorial Library Sub-Committee, he has recently completed 15 years service with his Company.

Mr. W. L. Pace, Associate Member, has recently been appointed an Assistant Grade B. in the Production Engineering and Machine Shop Department of Wulfruna College of Further Education, Wolverhampton. Mr Pace is a member of the Wolverhampton Section Committee, and a past Hon. Secretary of the Wolverhampton Graduate Section Committee.

Mr. S. Parnell, Associate Member, has been appointed Deputy to the Chief Engineer of the Holman Group, Camborne, Cornwall.

Mr. W. Pilkington, Associate Member, has relinquished his position as Chief Planning Engineer with Bristol Siddeley, Sunderland, factories, and has taken up an appointment as Production Engineer with Hobourn Aero Components Ltd., Strood, Rochester.

Mr. J. Pearce, Associate Member, has recently been appointed Chief Planning Engineer of Bristol Siddeley Engines Ltd., Sunderland. He was formerly Deputy Chief Planning Engineer.

Mr. M. J. Sargeaunt, Associate Member, has taken up an appointment as Principal Lecturer in Industrial Engineering and Management at the College of Advanced Technology, Loughborough. Mr. Sargeaunt is a member of the Institution's Editorial Committee.

Mr. T. Stuchbery, Associate Member, has relinquished his position as Development Engineer of Thos. Mercer Air Gauges, Redbourn, to practise as a consultant in the air gauging and automatic gauging design field.

Mr. E. L. J. Thorne, Associate Member, is now Lecturer in Management and Production Engineering subjects at the Redditch College of Further Education, Redditch, Worcs.

Mr. E. A. Turner, Associate Member, has relinquished his position with the Inspectorate at the Atomic Weapons Research Establishment, Aldermaston, and has taken up the appointment of Chief Inspector with the Saunders Valve Company, Cwmbran, Monmouthshire.

Mr. P. H. C. Waddington, Associate Member, has relinquished his appointment as Chief of Standardisation with English Electric Aviation—G.W. Division, and has taken up the position of Standards Engineer with Molins Machine Co. Ltd.

Mr. S. Jessop, Associate, has been appointed Manager of the Works of Thos. W. Ward, Ltd., Scotstoun, Glasgow, and is now in charge of Ward's engineering interests in Scotland.

Mr. B. L. J. Hart, Associate, is now Principal of the Computer Application Training Centre at Bradenham Manor, Bucks. Mr. Hart was formerly a member of I.C.T.'s Computer Group, and is well known for his lectures on management and production control.

Mr. A. J. Barbasio, Graduate, is now a Lecturer in Applied Mechanics at Poplar Technical College.

Mr. D. W. Alcock, Graduate, is now an Instrument Technician with Courtaulds Ltd. He was formerly Tool Draughtsman with De Havilland Aircraft Co.

Mr. J. F. Baugh, Graduate, has relinquished his appointment with Joseph Lucas (G.T.E.) Ltd., and is now Assistant to the Managing Director of Beauproducts Limited, Willenhall, Staffs.

Mr. W. H. Beck, Graduate, has taken up the appointment of Planning Engineer at Bristol Siddeley Engines Limited, Coventry. He is also a part-time Lecturer in Production Engineering at the Lanchester College, Coventry.

Mr. C. W. Chapman, Graduate, is now a Development Engineer with Gamet Products Ltd., Colchester. He was previously with the Hoffman Manufacturing Co. Ltd., Chelmsford.

Mr. R. R. Davies, Graduate, has relinquished his appointment with A. V. Roe & Co. Ltd., Woodford, Cheshire, and is now a Project Engineer with Teddington Aircraft Controls Ltd. (Bellows Division), Swansea.

Mr. R. W. Dean, Graduate, has taken up an appointment as Deputy Head of Products Group, Ranco Limited, Plymouth.

Mr. D. Hampson, Graduate, who was formerly Assistant to the Gold Film Production Supervisor, is now Gold Film Production Supervisor with Triplex Safety Glass Company Ltd., Kings Norton.

Mr. L. E. Henson, Graduate, has recently relinquished his position with the U.K.A.E.A., to take up an appointment as Commissioning Engineer with Atomic Power Constructions Ltd.

Mr. J. L. Hignett, Graduate, has relinquished his appointment as Assistant Works Manager, Belling & Lee, Liverpool Division, to take up an appointment as Works and Development Engineer, British Vacuum Flask Co. Ltd., Huyton, nr. Liverpool.

Mr. L. J. Homer, Graduate, has recently completed a one-year post-graduate course in Precision Engineering at the College of Aeronautics, Cranfield, and was awarded the Diploma in Advanced Engineering. He has now returned to the appointment of Production Engineer at Bristol Aircraft Limited.

Mr. L. W. N. Jones, Graduate, formerly a Planning Engineer with the Motor Accessory Division of S. Smith & Sons, has taken up an appointment as Production Engineer with Gillette Industries Ltd.

Mr. P. D. Mitchell, Graduate, formerly Assistant Sales Manager of Kolypenco Ltd., has been appointed Technical Sales Manager.

Mr. D. R. Munt, Graduate, is now Apprentice Supervisor with John Mowlem Limited, Hatfield, Herts.

Mr. J. P. Noble, Graduate, has taken up an appointment as Work Study Engineer for a group of Companies : Sunderland Engineering Equipment Co. Ltd., Wear Winch & Foundry Co. Ltd., Sir James Laing & Sons Ltd. (Shipbuilders).

Mr. T. J. Smith, Graduate, has relinquished his appointment as Jig and Tool Draughtsman with Sperry Gyroscope Ltd., and has taken up a position as Research and Development Planning Engineer with J. Langham Thompson at their Stanmore Laboratories.

Mr. B. Symonds, Graduate, is now a Consultant Engineer for Cleer Designs Limited, Coventry.

Mr. G. W. Taylor, Graduate, has been appointed Assistant Lecturer at the West Park College, Sunderland.

Mr. L. Walker, Graduate, has been recently appointed Assistant Manager (Rolling) in the Billet Mill of Samuel Fox & Co. Ltd., Stocksbridge.

Mr. H. F. Warren, Graduate, of the British Scientific Instrument Research Association, has been awarded the Ellis Memorial Award, silver medal and

Mr. N. R. Webster, Graduate, had taken up an appointment as Planning Engineer and Assistant to Works Manager with John Thornton (Engineers) Limited, West Molesey.

Mr. P. Wild, Graduate, is now a Design Draughtsman with Cylinder Components Limited, Birmingham.

Mr. I. M. Woods, Graduate, is now a Management Consultant with Wortley, Hawson and Camm Limited, Sheffield.

Obituary

The Institution records with regret the death of **Mr. D. L. Deshpande,** Member, Director of the Bihar Institute of Technology, Sindri, India.

Mr. Deshpande, who was also Chairman of the Mechanical Section of the Institution of Engineers (India), had been a member of the Calcutta Section for over ten years, and played a considerable part in the Section's affairs.

Hazleton Memorial Library

ADDITIONS

The Hazleton Memorial Library is a reference and lending library freely available to members of the Institution. It is open on every weekday, excepting Saturdays and public holidays, from 10 a.m. until 5.30 p.m. Members may borrow all books and periodicals, with the exception of those which are constantly required for reference, and the current numbers of periodicals. The initial loan period is one month, and this can often be renewed upon application to the Librarian. Applications for loans, loan renewals, and for information can be made by post and telephone by members unable to visit the library; and books and periodicals can be sent to members by post, the Institution paying the cost of postage one way.

Advisory Council on Scientific Policy. **"Annual Report, 1959-1960."** *London, H.M.S.O.,* 1960. 32 *pages.* 1s. 9d. Cmnd 1167.

Angus, Harold T. **"Physical and Engineering Properties of Cast Iron: A Data Book for Engineers and Designers."** *British Cast Iron Research Association, Alvechurch, Birmingham,* 1960. 528 *pages. Folding Plates, Charts. Tables. Diagrams.*

This book by the Deputy Director of the British Cast Iron Research Association is divided into nine parts dealing respectively with the constitution and structure of cast iron: the mechanical, physical and electrical properties of cast iron; the general properties of commercial cast iron; special properties affecting service; heat treatment of grey cast iron; internal stresses; components with high local loadings; cast iron beams, columns, pipes, cylinders and pressure vessels; and applications of specifications and data to design. Each part and section is copiously furnished with references and standard data.

Benson, F. A. **"Problems in Electronics with Solutions."** 2nd edition, revised and enlarged. *London, Spon,* 1961. 249 *pages. Charts. Diagrams.*

The first section of this book presents the problems with the answers; and the second, a working out of the solutions. This book is designed to provide a course in electronics for undergraduates and a few questions of a higher standard have been included.

Beverstock, A. G. **"Modern Apprenticeship: A Short Guide for Employers, Managers, Employment Officers, Teachers, Parents and Others Concerned with the Training of Youth."** *London, Classic Publications,* 1958. *Reprinted* 1960. 83 *pages.* 10s. 6d.

Contents: Types of apprenticeship — Modern principles — The educational system — Selection — Reception and introduction — The indenture — Basic preliminary training — College courses — Sandwich courses — Clerical and administrative schemes — Apprenticeship for girls — Group apprenticeship — The Associated Examining Board — Widening horizons — The White Paper on technical education — Publicity — National Service.

Briggs, Andrew J. **"Warehouse Operations Planning and Management."** *New York and London, Wiley,* 1960. 302 *pages. Illustrations. Diagrams,* 68s.

The planning of warehouses and their administration.

Contents: Study the problem — Know your space — Select your pallet — Design your pallet rack next — Plan for retail bins — Selecting your kit of tools — Planning the layout and computing storage and requirements — Additional miscellaneous equipment you will need — Development of storage aids — Conveyors: powered and non-powered — Design of stock location system — Operating procedures are essential — Keep control of your space — Management reports and statistics — Picking your orders — The palletised load — Some general warehousing practices.

British Communications and Electronics. **"The Transistor Era: A Guide to Transistors and Associated Semi-Conductor devices."** *London, Heywood,* 1959. 66 *pages.* 5s. For reference only.

Contents: Semi-conductors: some fundamentals — Semi-conductor diodes: the state of development — Semi-conductors: the world position — British transistor manufacture: a report of progress — A survey of semi-conductor photo-sensitive devices — Buyers' guide to transistors and associated semi-conductor devices and accessories — Manufacturers' index.

British Constructional Steelwork Association, London. **"Examples of Structural Steel Design to Conform with the Requirements of B.S. 449 : 1959."** *London, the Association,* 1960. 66 *pages. Diagrams.*

British Constructional Steelwork Association, London. **"The Use of Welding in Steel Building Structures."** *London, the Association,* 1960. 35 *pages. Diagrams.*

British Standards Institution, London. **"Lifting Tackle edited by L. Linder. Part 1: Ropes and Fittings. Part 2: Chains and Fittings."** New edition. 2 Volumes. *London, the Institution,* 1959 - 1960. 417 *pages and* 574 *pages. Illustrations. Diagrams.* (British Standard Handbook No. 4.)

A digest of standards statutory requirements and other useful information.

Giedion, Siegfried. **"Mechanisation Takes Command: A Contribution to Anonymous History."** *New York, Oxford University Press,* 1948 (*reprinted* 1955). 743 *pages. Illustrations. Diagrams.* 80s.

An historical study of the influence of mechanisation on human lives and environment; a technological partner to the numerous history books in which man is considered in his social, political, economic or artistic environment. The book is popular in character but contains a fairly high degree of specialised technical information. Subjects dealt with include agriculture and food preservation; sanitation; household furniture and appliances; and heating and cooking. Certain means and auxiliaries of mechanisation (e.g., standardisation; scientific management, assembly lines and interchangeability) are studied There are numerous illustrations.

Harper, F. C. and Stone, P. A. **"Floor Finishes for Factories."** *London, H.M.S.O.,* 1960. 10 *pages. Tables.* 1s. 9d. (Factory Building Studies No. 3, D.S.I.R. Building Research Station.)

This gives general guidance on floor surfaces. It discusses general-purpose floors and those designed for special purposes. It also gives examples of initial costs based on actual quotations from contractors. Consideration of the conditions of use to which the surface will be subjected, and possible maintenance costs are also given.

Hedges, Ernest S. **"Tin and Its Alloys."** *London, Edward Arnold,* 1960. 424 *pages. Plates. Illustrations. Diagrams.* £6 6s.

This comprehensive book includes some historical information and photographs of artistic interest, as well as extensive bibliographies appended to each chapter.

Contents: Introduction (including history)—Tin in cast and wrought forms—Physical metallurgy of tin and its alloys— The chemical behaviour of tin—Electro-deposition of tin and its alloys—Hot-tinning—Tinplate—Tin in bearing alloys—Die casting and other tin alloys —Solders—Bronzes.

Higgins, Raymond A. **"Engineering Metallurgy: Part 2 Metallurgical Process and Technology."** *London, English Universities Press,* 1960. 404 *pages. Illustrations. Diagrams.* 25s. (Higher Technical Series).

Part 1 of this work deals with the basic principles of applied physical metallurgy. Part 2 deal with industrial metallurgical processes. It is suitable as a text-book for the Associateship examinations of various engineering institutions, and in part for the examinations of The Institution of Metallurgists. The author approaches his subject on the assumption that the responsibilities of technical control of metallurgical processes will fall upon an engineer rather than upon a specialist metallurgist.

Contents: The industrial melting of metals and alloys — Ingot casting — Sand casting — Die casting — Other casting processes — Powder metallurgy — The rolling of metals — Forging processes — Extrusion — Drawing rod, wire and tubes — Deep drawing and allied processes — Miscellaneous cold working processes — The heat treatment of steel — The heat treatment of non-ferrous metals and alloys — Pressure welding processes — Soldering and brazing — Arc welding processes — Welding with a chemical heat source — "New" metals.

International Congress of Scientific Management, **"Papers Presented."** No. 12, *Sydney and Melbourne,* 1960. In folder.

Institution of Metallurgists, London. **"Progress in Metallurgical Technology: Lectures Delivered at The Institution of Metallurgists Refresher Course, 1959.** *London, Iliffe for the Institution,* 1960. 147 *pages. Illustrations Diagrams.* 32s. 6d.

Contents: Taylor, John. Modern developments in iron and steel production — Bradshaw, A. V. Extraction and refining of non-ferrous metals — Robiette, A. G. Melting of ferrous and non-ferrous metals — Atterton, D. V. Casting of ferrous and non-ferrous metals.

Livshits, A. L. **"Electro-erosion Machining of Metals."** Trans. by E. Bishop. Edited by R. S. Bennett. *London, Butterworths, in association with the Department of Scientific and Industrial Research,* 1960. 115 *pages. Illustrations. Diagrams.* 30s.

Based on work carried out in Russia by the author and a group of colleagues at KB, MS and IP, the ENIMS laboratory of electrical working methods and the electrical machines group at the "V.I. Lenin" Polytechnic Institute at Kharkkov. Electro-erosion machining methods are in a nearly stage of development, and the author thought it useful to attempt a description of these methods from the simple physical viewpoint, to establish general laws holding good for the various types of electro-erosion processes and to introduce a number of definitions and classifications.

Contents: Physical conditions for cutting by electro-erosion process — The generation of current pulses — Automatic control of the machining process — Electro-technological characteristics — Machine tools for dimensional electro-erosion machining of metals.

Miles, H. G. and Elen, L. W. F. **"Worked Examples in Workshop Mathematics."** *London, Cleaver-Hume Press,* 1960. 128 *pages.*

Suitable text-book for The City and Guilds Intermediate Machine Shop Engineering Examination.

Miller, R. N. B. **"Plastics moulds."** *Brighton and London, Machinery Publishing Co. Ltd.,* 1959. 58 *pages. Illustrations. Diagrams.* (Machinery's Yellow Back Series.)

An introduction to the design and construction of moulds used in the production of articles in the various plastics materials. Injection and compression moulds are discussed.

Ministry of Aviation. **"Research Careers in The Ministry of Aviation."** *London, Ministry of Aviation and Central Office of Information,* 1960. 15 pages. Gratis.

Monday, C. **"Broaching."** *Brighton and London, Machinery Publishing Co. Ltd.,* 1960. 160 *pages. Illustrations. Diagrams.*

Deals with the working of modern broaching machines and gives details of some of the specialised cutting tools associated with them for internal and surface broaching.

Organisation for European Economic Co-operation, Paris, European Economic Agency. **"Simplification, Standardisation, Specialisation: Case Studies on Variety Reduction."** Vol. 2. *Paris, the Organisation,* 1959. 97 *pages. Illustrations. Diagrams. Tables.*

Contents: Case study on the influence of the assortment on the customer-sale staff relationship in a department store — Case study of variety reduction carried out in an Italian firm manufacturing compressors — Variety reduction in the paper trade — Case study of variety reduction carried out by a stove factory — Analysis of purchasing and selling of a Dutch wholesale company.

Ranson, H. B. and Webb, E. T. A. **"Direct Current Machines."** 2nd. edition. *London, Cleaver-Hume Press,* 1960. 320 *pages. Illustrations. Diagrams.* 21s.

The first edition of this book was published in 1952: Revision has been demanded only by the inevitable charges in industrial and economic emphasis and by the need to employ m.k.s. units in such modest mathematical treatment as is called for.

Contents: Introduction — Dynamo-electric machines — The field system and armature core — the armature winding — The commutator and brush gear — The materials of construction — Generator E.M.F. and armature reaction — Commutation — The characteristics of D.C. generators — The direct current motor — The characteristics of D.C. motors — The D.C. motor starters — Speed control — Enclosures: rating of D.C. machines — Applications of D.C. machines — Some test questions — Answers to numerical questions.

Renfrew, A. and Morgan, Phillip. **"Polythene: The Technology and Uses of Ethylene Polymers."** 2nd Edition. *London, Iliffe; New York, Interscience Publishers,* 1960. 781 *pages. Illustrations. Diagrams.* £8 5s.

An extensive and thorough revision of the first edition which was published in 1957. A comprehensive and detailed survey of the manufacture, processing, fabrication and applications of polythene.

Contents: *Manufacture and properties*: The history of polythene — Manufacturing processes — The theory of ethylene polymerisation by free radicals and the kinetics of the high pressure reaction — The theory of ethylene polymerisation by ionic growth — The structure of polythene — Oxidation and ageing — Dielectric properties — General mechanical properties — Chemical resistance and physical-chemical properties — Testing and specifications — Low molecular weight polythenes — Radiation treatment of polythene — Ethylene copolymers and polymer blends — Modified polythene. *Processing techniques*: Compounding — Pigmentation — Extrusion problems and screw design — The extrusion of tube, rod and profile — The extrusion of polythene flat film, tubular film and sheet — Injection moulding — Blow moulding — Centrifugal casting of large diameter pipe — Extrusion coating and laminating — Dip coating — Spray coating — Vacuum forming — Processing of polythene. *Applications*: Cables and other dielectric applications — Film applications — Polythene coated packaging products — Packaging applications of polythene other than film — Polythene pipe for cold water services — Chemical plant — Household goods — Textile yarns and fabrics. *Appendices*: World capacity of polythene — Polythene trade names.

Rider, H. G. **"Workshop Engineering Practice: An Introductory Course for Engineering Students and Apprentices."** *London, Iliffe,* 1959. 150 *pages. Diagrams.*

This work is Volume 1 of a series, and deals with fitting. Other volumes will deal with, sheet metal work; materials; welding; and foundry work.

Contents: Saws and shears — Files and filing — Scrapers and scraping — Cutting screw threads and reaming holes—Measuring instruments—Marking out—The drilling machine. The book is intended for students at secondary modern and junior technical schools and for those taking the craft examinations at The City and Guilds of London Institute.

Robertson, Struan A. **"Engineering Management."** (2nd Edition). *London and Glasgow, Blackie,* 1960. 467 *pages.* 30s.

The first edition of this work was published in 1948, and was prepared as a basis for a course of lectures at Battersea Polytechnic to University and H.N.C. engineering students, and others working for the Industrial Administration Examination of the I.Mech.E. The second edition has been brought up-to-date where necessary. The text-book is wide in scope; gives a bird's eye view of the whole subject, while serving as an introduction to the special branches of knowledge and techniques which contribute to scientific management. There are lists of references for further reading at the end of each chapter, and a list of 217 management problems for discussion and solution. Many of these are taken from the examination papers of The Institutions of Mechanical and Production Engineers.

Contents: Part 1. *The Art of Management.* Initiative. Part 2. *The Science of Management.* Scientific method—Engineering science—Economics the science of wealth—The structure of industry—The legal background—The development of scientific management. Part 3. *The Practice of Management.* Preliminary investigation (Market research; Design; Production planning; Estimating.) —Formulating policy. (The general policy and budget.)—Organisation. (Forming a partnership or a company; The management team); The factory. (The location of the factory; Equipment, Materials; Factory layout)—The workpeople. (Employing labour; Training; Industrial health)—Production (Production control; Inspection.)—The customer (Sales)—The controls (Management controls; The financial accounts)—Conclusion. Day-to-day management — Management problems.

Sacks, Raymond J. **"Theory and Practice of Arc Welding."** 2nd edition. *Princeton, N.J., London, Van Nostrand,* 1960. 478 *pages. Illustrations. Diagrams.* 45s.

A course of study in arc welding theory and practice in accordance with recommendations of the American Welding Society. It is designed for students, and is based on the Society's "Code of minimum standards for instruction of welding operators". There are instructions for practical exercises and suggestions for the instructor.

Shand, E. B. **"Glass Engineering Handbook."** 2nd edition. *London and New York, McGraw-Hill,* 1958. 484 *pages. Illustrations. Diagrams.* 77s. 6d.

A handbook of the composition, manufacture, properties and applications of glass as an engineering material.

Contents: Glass technology — Glass manufacture — Applications — Fibrous glass — Appendixes (Federal and military specs. Definition of glass terms.)

Shaw, Anne G. **"The Purpose and Practice of Motion Study."** 2nd edition. *Manchester and London, Columbine Press,* 1960. 324 *pages. Illustrations. Diagrams.* 50s.

The first edition of this classic work was published in 1952. The second edition, while following the pattern of the first is brought up-to-date, in accordance with developments which have taken place, and new case studies have been added. The term "motion study" is retained in the title in order to establish the identity of the work, despite the fact that "method study" is the term adopted by the B.S.I. and is widely used. The author, however, emphasises that the subject of the book is "Method Study"; and the grouping of the chapters is more or less in accordance with the B.S.I. definition of the term. No space is devoted to "Time Study" or, as it is now called "Work Measurement", not because the subject is unimportant but because "it deserves a volume to itself which may some day be a companion to this."

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"Spark Machining." *Brighton and London, Machinery Pub. Co.*, 1960. 72 *pages. Illustrations. Diagrams.* (Machinery's Yellow Back Series, No. 46.) 5s. 6d.

Much of the material in this book has appeared in the the pages of the journal *Machinery*, but is supplemented by information made available by manufacturers of spark machining equipment. The book is a summary up-to-date guide to the process, and to the equipment available.

Contents: Introduction and basic principles — Spark machining equipment — Typical and special spark machining operations.

Stender, Richard and McKelvey, K. K. **"The Modern Slide Rule: A Manual of Self-Instruction for Schools, Colleges and the Professional User."** 3rd edition. *London, Cleaver-Hume Press,* 1960. 119 *pages. Diagrams.* 6s.

Teece, P. J. C. **"Foundations and Mountings for Diesel Engines."** *London, Diesel Engineers and Users Association,* 1960. 22 *pages. Diagrams. Illustrations.*

Paper presented to the Association. Considers the principles of vibration isolation, and methods of isolation.

Theegarten, A and Geyer, M. **"Milling: The Design, Selection, Application and Maintenance of Milling Cutters, Examples of Economical and Unusual Milling Operations."** *Brighton and London, Machinery Publishing Co. Ltd.,* 1960. 74 *pages. Illustrations. Diagrams.*

Offers practical suggestions based on the result of many years' experience of Wanderer-Kerke, and shows how to carry out milling operations correctly.

Timoshenko, Stephen P. **"Engineering Education in Russia."** *London, New York, McGraw-Hill,* 1959, 47 *pages. Iluustrations. Tables.*

A brief history of the development of Russian engineering education, and a description of its present state. The author compares the educational system during prerevolutionary days, and in 1958 when he returned to Russia to visit engineering and technical schools. He describes some important Russian engineering schools and compares them to similar American schools.

Town, H. C. **"Die-sinking and Engraving Machines."** *Brighton and London, Machinery Publishing Company,* 1959. 70 *pages. Illustrations. Diagrams.* 5s. 6d. (Machinery's Yellow Back Series, No. 5.)

A practical guide to available machines.

Contents: Die-sinking and engraving machines — Electrical and electronic control of die-sinking —Hydraulic control — Pantograph machines.

Treasury, Organisation and Methods Division. **"The Practice of O & M."** *London, H.M.S.O.,* 1954. 51 *pages. Tables.*

Designed as a training manual for Civil Servants, but should be useful to others.

Tucker, Spencer A. **"Successful Managerial Control by Ratio Analysis."** *London, New York, McGraw-Hill,* 1961. 434 *pages. Diagrams.* 85s. 6d.

The author maintains that management can obtain more help than is common from the usual figures and statistics if these are properly interpreted and manipulated. He explains how to develop and apply the techniques of ratio analysis in a wide variety of situations and industries. The book develops 429 specific ratios and explains their functions and 154 charts typify and diagnose practical conditions in manufacturing by means of ratio movements.

Contents: How to get effective management — Tools for ratios and controls — Elementary ratios for evaluating production — Advanced ratios for evaluating production — Managerial control of production — Introduction to evaluation and control of sales function — Elementary ratios for evaluating sales effort — Elementary sales ratios for evaluating product activity — Advanced evaluation and control of sales function — The integration of production and sales — Introduction to financial management — Elementary evaluation of the capital structure — Elementary evaluation of financial management — Advanced evaluation and control of capital function — Integration of activities of production, sales and capital — Index of ratio formulas and descriptions.

Underwood, L. R. **"The Rolling of Metals, Theory and Experiment."** *London, Chapman and Hall,* 1952. Vol. 1. 344 *pages. Diagrams. Chart.*

The material in this book first appeared as a series of articles in *Sheet Metal Industries* and as a report for the Rolling Mill Sub-Committee of the British Iron and Steel Federation. The present volume covers the more fundamental aspects of the subject such as forward slip, friction, and method of calculation of the rolling load based on them.

United Steel Companies. **"This is United Steel."** *Sheffield, the Company,* 1960. 55 *pages. Photographs.*

Weldford, A. T. **"Ergonomics of Automation."** *London, H.M.S.O.,* 1960. 60 *pages. Illustrations. Diagrams.* (Department of Scientific and Industrial Research. Problems of progress in Industry No. 8.) 3s. 6d.

The purpose of this pamphlet is to survey some of the aspects of ergonomics which are likely to bear on the questions of designing automatic machinery.

Contents: The ergonomic approach to automation — Design for ease of operation — Maintenance work — Some problems of personnel — Conclusion.

Westminster Chamber of Commerce. **"List of Members and Classified Directory 1961."** *London, Westminster Chamber of Commerce,* 1961. 184 *pages.* Reference only. Not for loan.

"Year Book of The Heating and Ventilating Industry." *London, Technitrade Journals Ltd.,* 1960. 506 *pages.* 15s. Reference only. Not for loan.

Includes information on design, recent literature, British Standards, wages, labour and trading regulations and agreements; manufacturers addresses, technical and trade associations, and a list of members of the Association of Heating, Ventilating and Domestic Engineering Employers.

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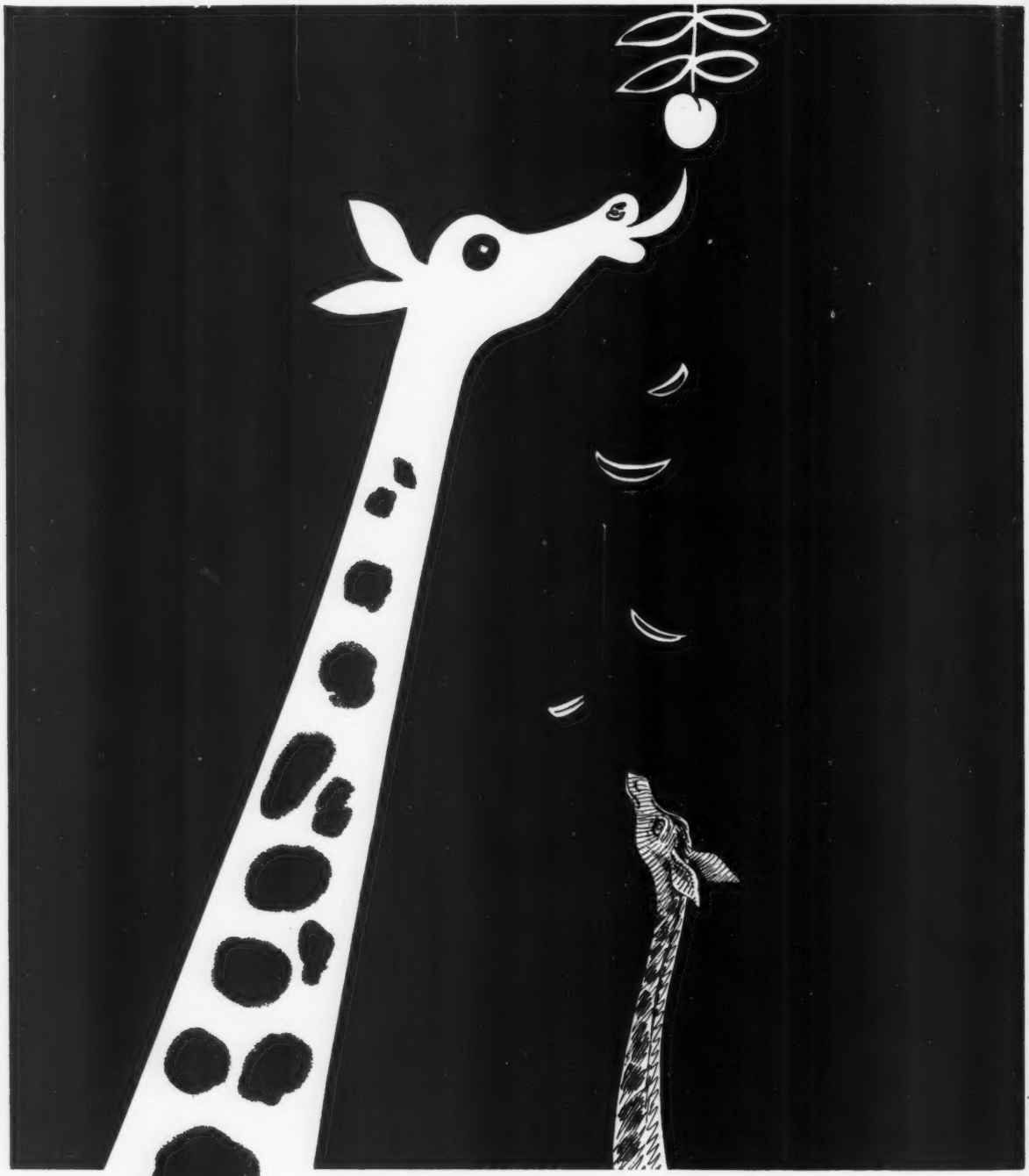

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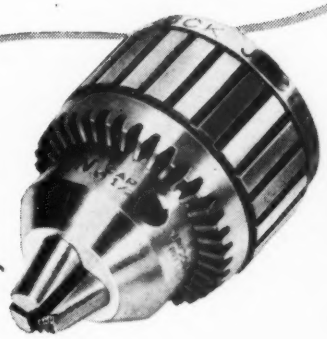

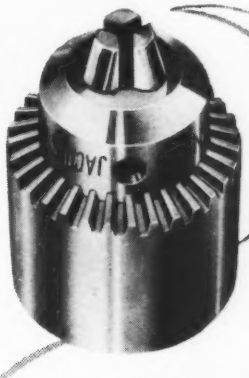

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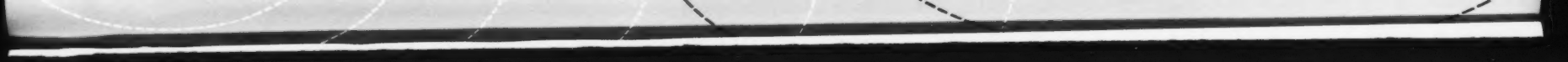

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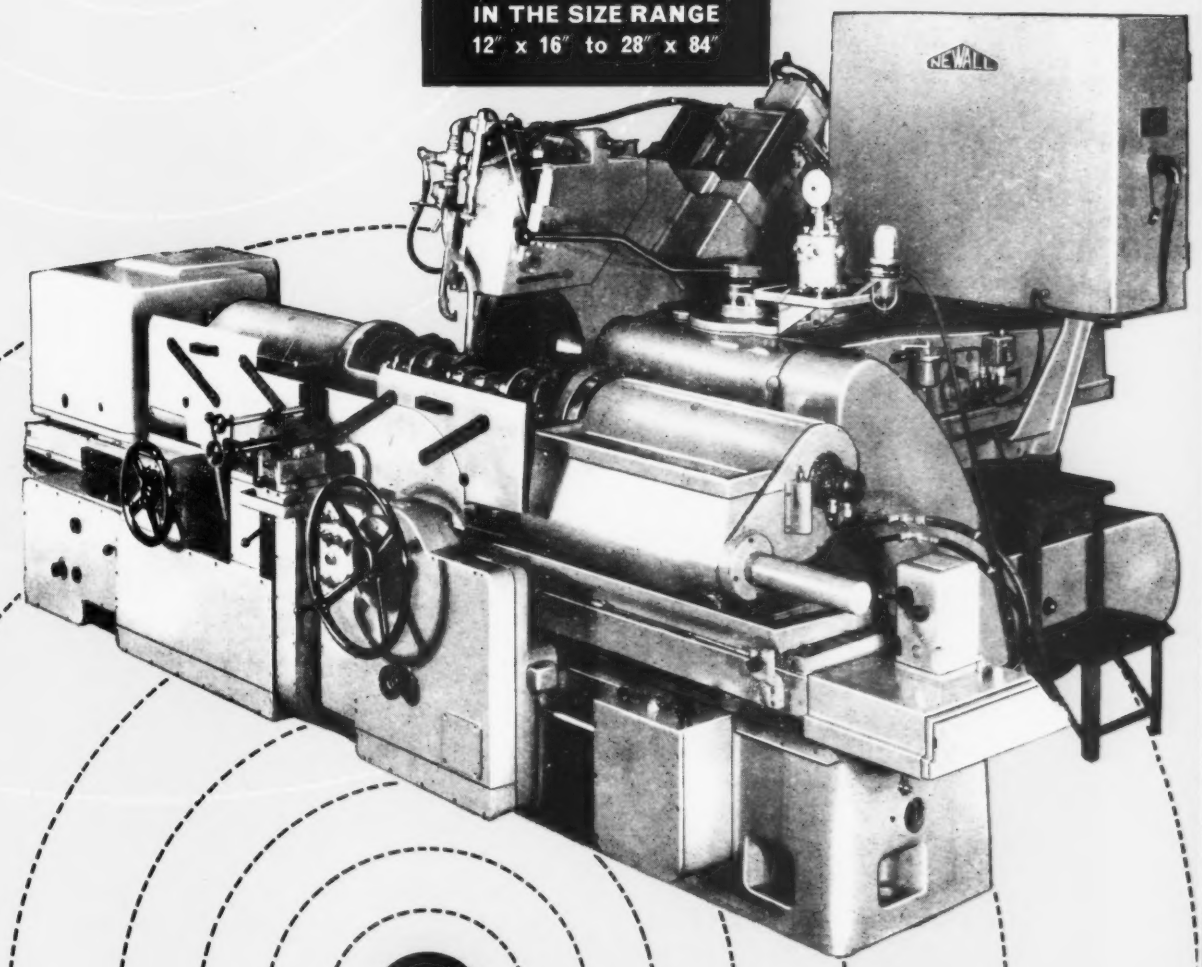

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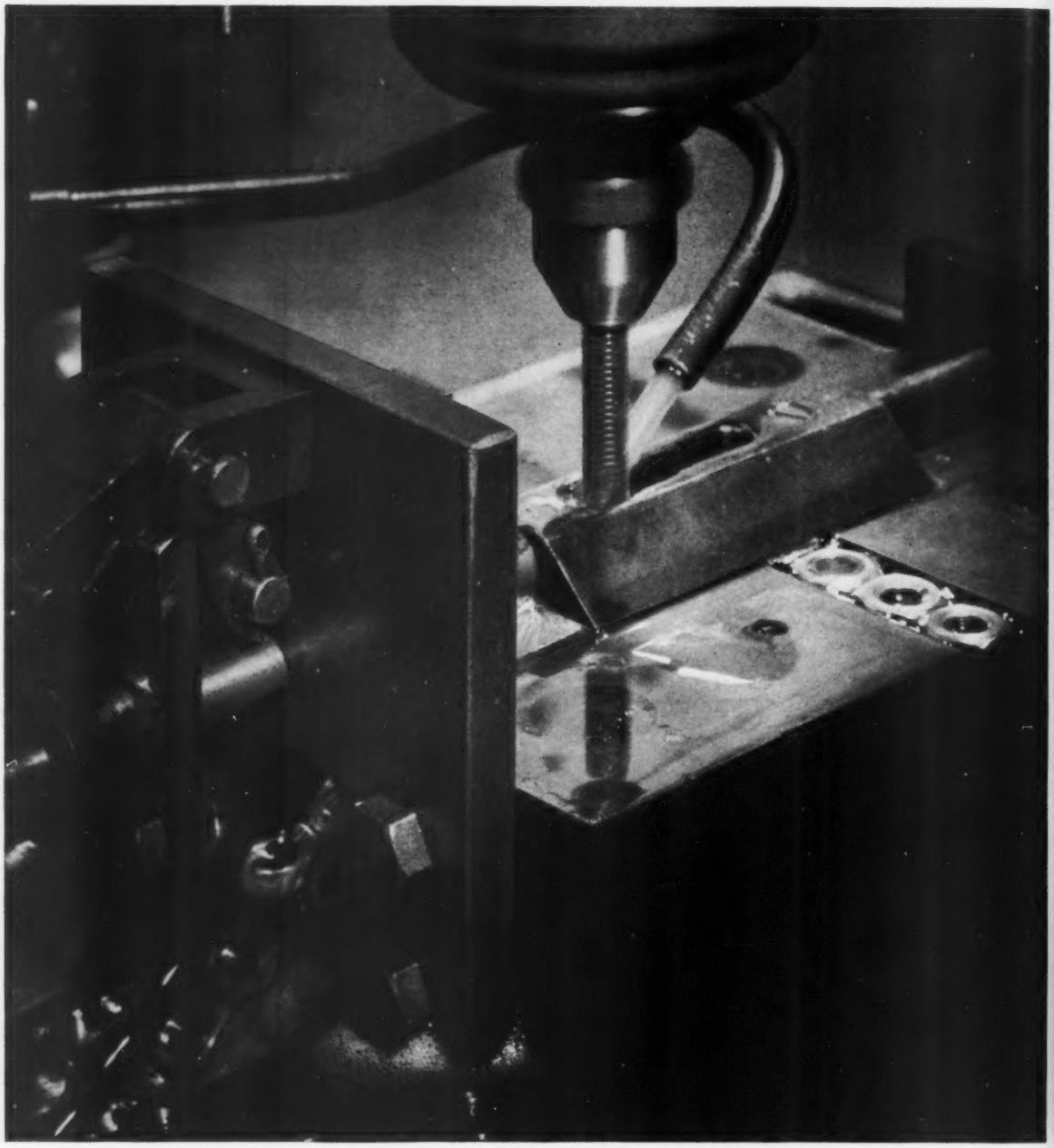
Shell achievement



A famous aero-engine firm found it could drastically reduce the cost of producing nuts made from S.62 steel, by changing over from conventional cutting oils to Shell Garia Oil 115. The facts are these. S.62 steel is heat-resistant and stainless. The quality of this steel and the call for very fine tolerances, as well as a very high percentage of full depth of thread, presented costly manufacturing problems. The breakage of taps, the need for constant re-setting, and the high proportion of rejects, built up the average cost of the nuts to over 1/2d. each.

By accepting the advice of the Shell engineer and changing over to Shell Garia Oil 115, this firm was able to produce 3,000 nuts between regrinding taps–resulting in the cost of each nut being reduced to 3d.

Write for the booklet 'Selecting Your Cutting Oils' to Shell-Mex House, London, W.C.2

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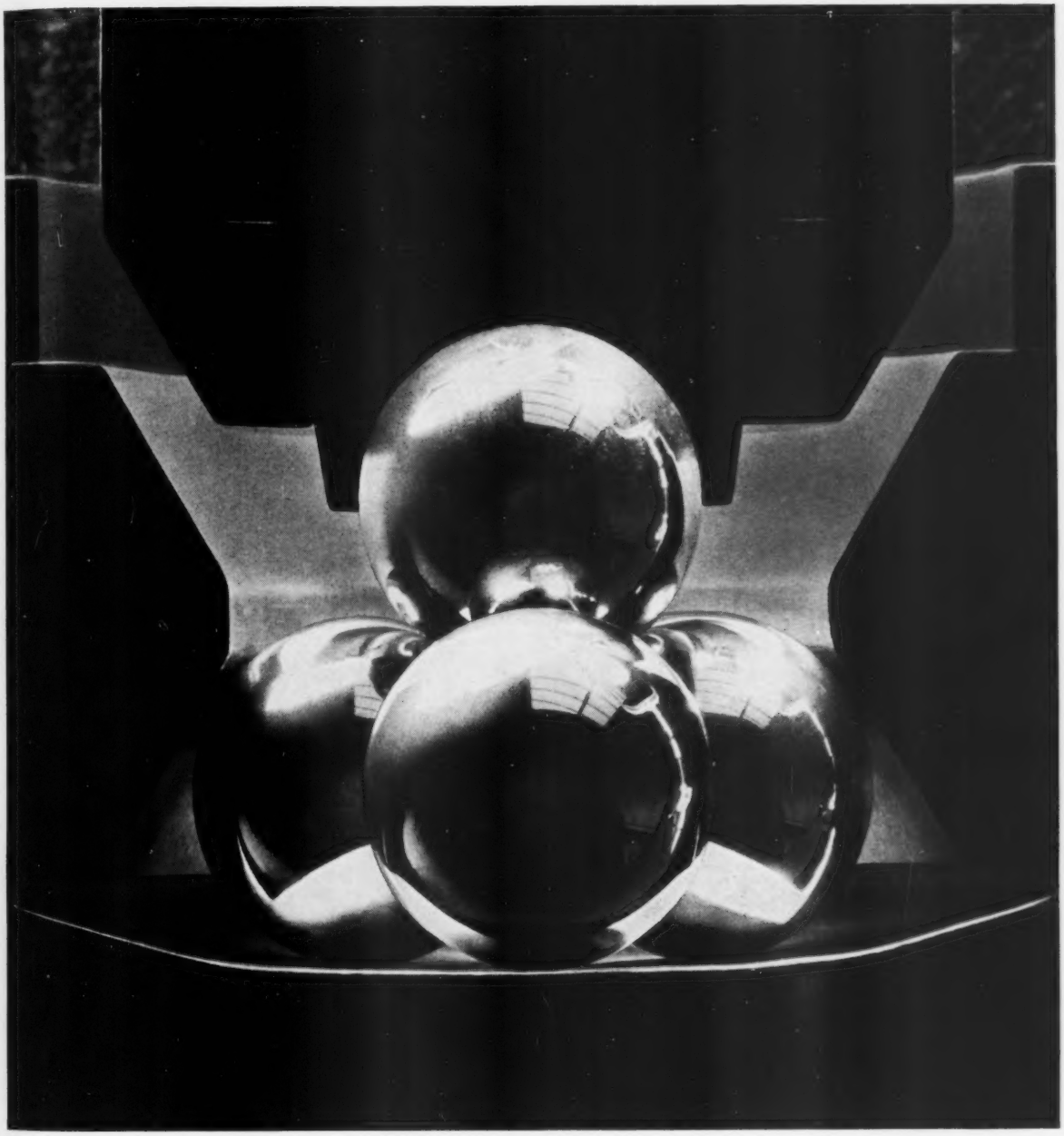
SHELL INDUSTRIAL OILS

Shell demonstration



To establish *facts* is the constant preoccupation of Shell research. Assumptions cut no ice.
For example, how 'extreme' is 'Extreme' Pressure?
To evaluate scientifically the respective performance of the many E.P. agents evolved, Shell devised the Four Ball Test machine illustrated.
In this apparatus a clamped ½" diameter steel ball revolves in contact with three identical static balls in a metal cup containing the additive to be tested. Pressure between the balls can be varied at will. Under these controlled rubbing conditions, coefficients of friction can be plotted against load. With increasing loads, wear scars formed at successive stages may be measured and the welding point accurately determined. Developed for basic research, the Four Ball Test also plays an important workaday role in ensuring consistent batch quality—of prime importance on the machine-shop floor.
Thoughtful production executives who want to know more have only to write for the book, *'Selecting Your Cutting Oils', to Lubricants Dept., Shell-Mex House, London, W.C.2.*

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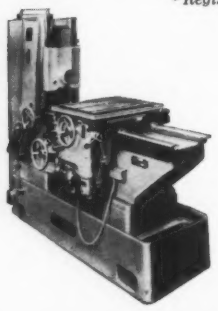

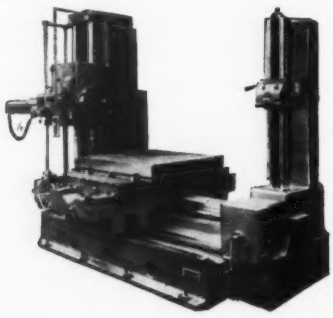

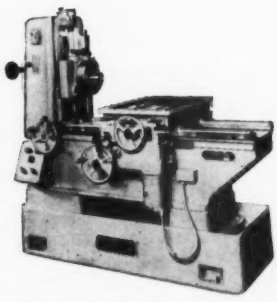

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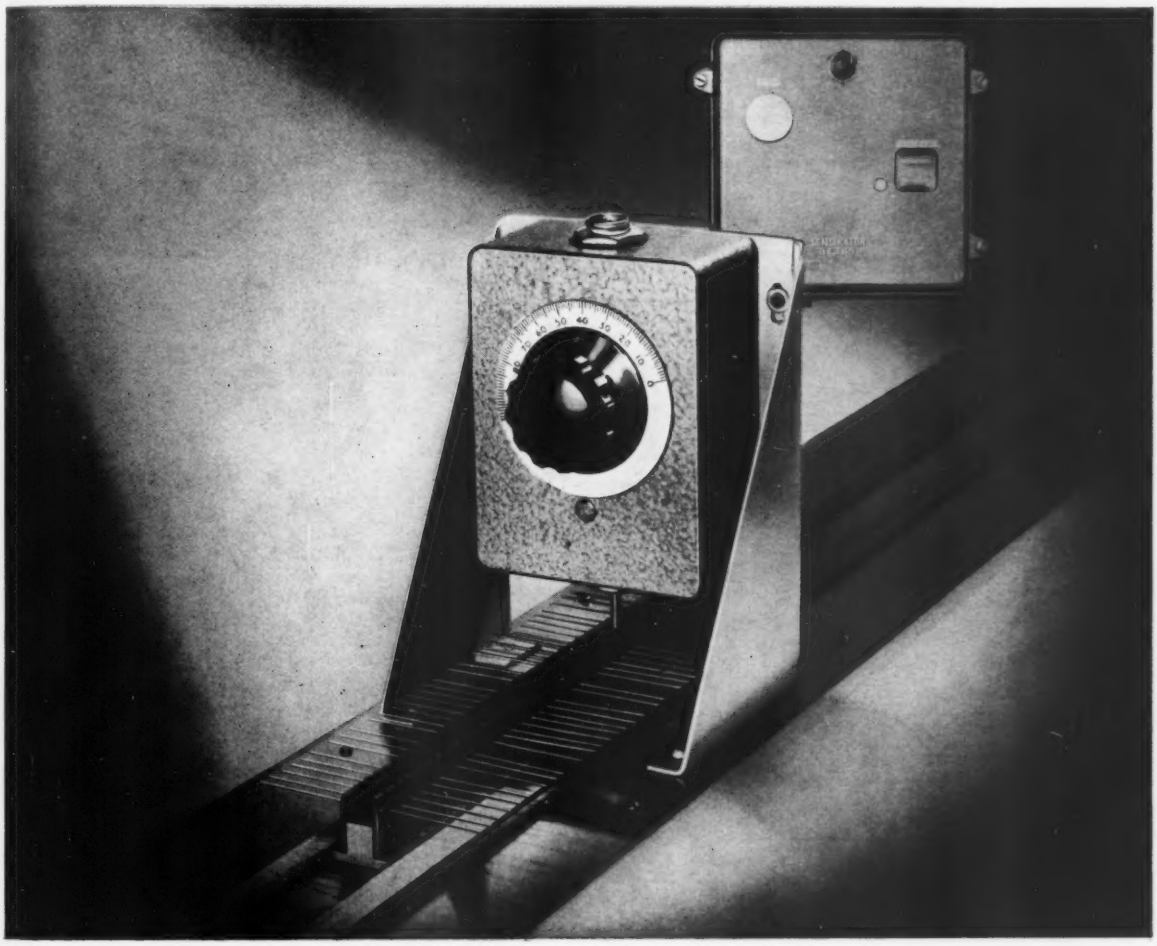

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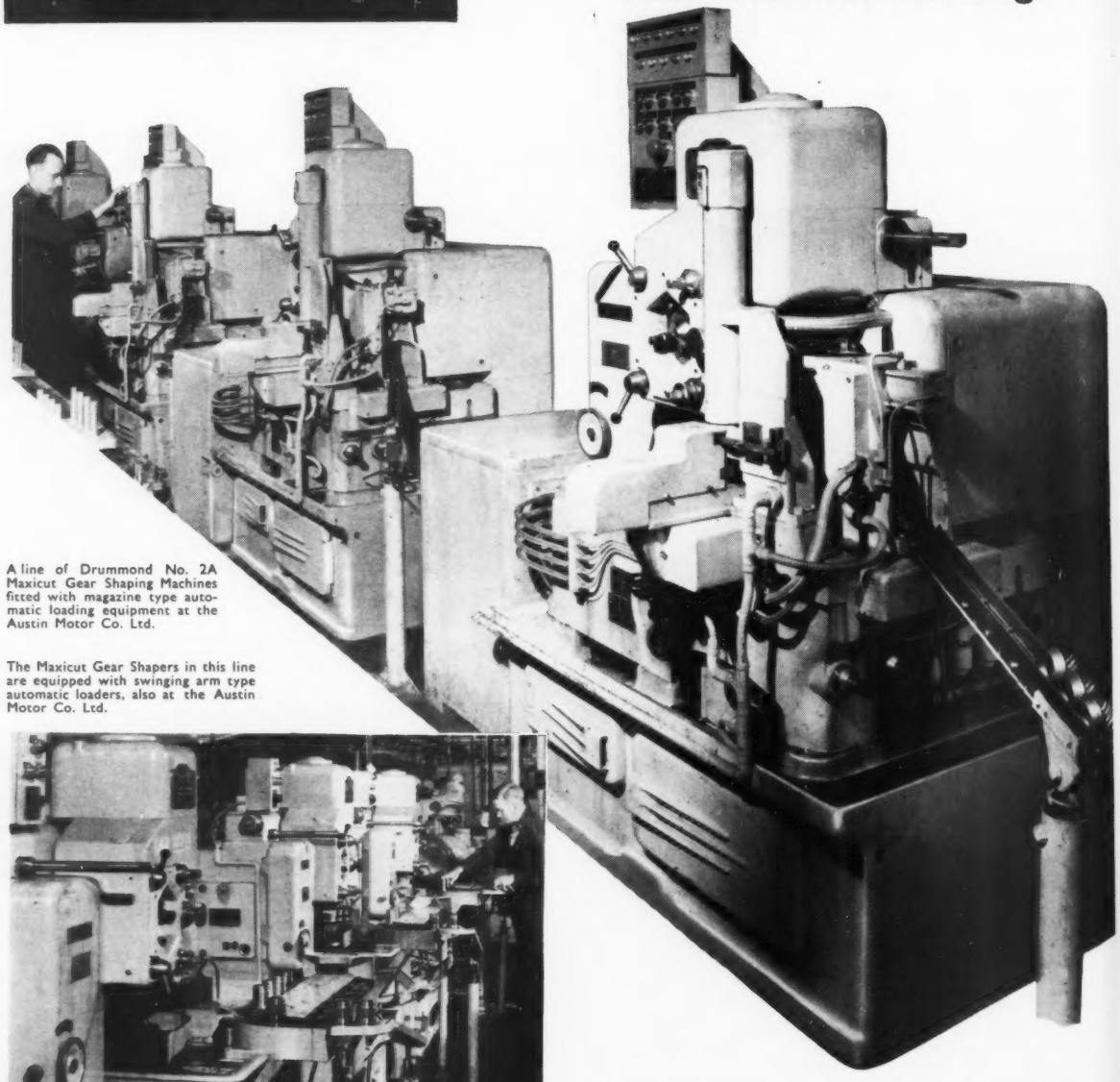
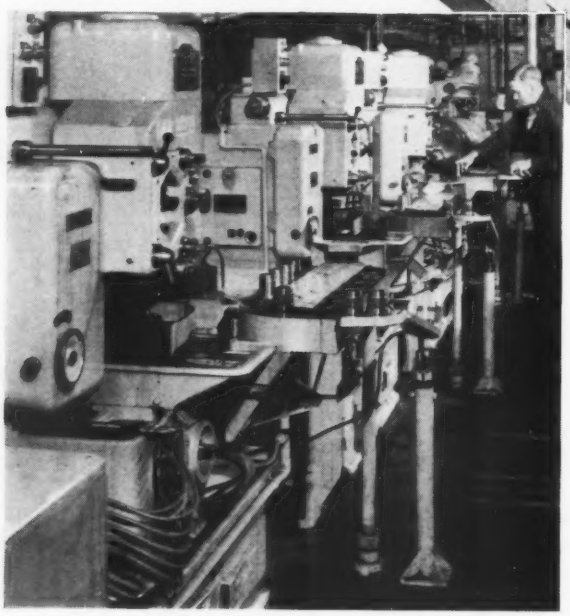
with Automatic Loading



A line of Drummond No. 2A Maxicut Gear Shaping Machines fitted with magazine type automatic loading equipment at the Austin Motor Co. Ltd.

The Maxicut Gear Shapers in this line are equipped with swinging arm type automatic loaders, also at the Austin Motor Co. Ltd.



For the mass production of automobile gears, Maxicut 2A Gear Shaping Machines can be arranged with either magazine or swinging arm type Automatic loading as illustrated. The equipment is generally adaptable for use on a wide range of components for cutting gears, splines, etc. Write today for further details.

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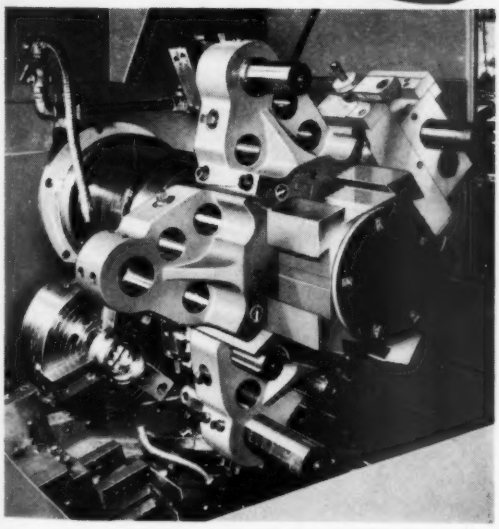
2AC *Automatic* for Versatile Production

The view below shows a 2AC tooled by a British customer for the production of commercial vehicle gear blanks.



You complete more jobs on the 2AC Single Spindle Chucking Automatic, fewer second operations are needed and standard tool and machine functions will handle most work. Built-in rigidity and accuracy are features that ensure the holding of close tolerances and speeds and horsepower permit effective use of today's most advanced cutting tools. Because of their fast set-up features batchwork can be produced more profitably on an automatic basis. A 12" air operated chuck is fitted.

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On the right can be seen a typical arrangement of cutter blades on the table of a Snow Surface Grinding Machine.

SNOW

SURFACE GRINDING MACHINES

for continuous and accurate production

Fourteen of these vertical surface grinding machines are installed at the Tenbury Wells factory of Richard Lloyd Limited, and as shown in the close-up view on the right they are extensively used for rough grinding cutter blades for the well-known range of "Galtona" Serrated Blade Cutters.

The V type Snow machine is specially suitable for heavy duty requirements — hydraulic reciprocation of the table gives variable speeds up to 100 ft. per min. with shockless reverse and design features ensure maximum ease of control and minimum "down-time" for serving and maintenance.

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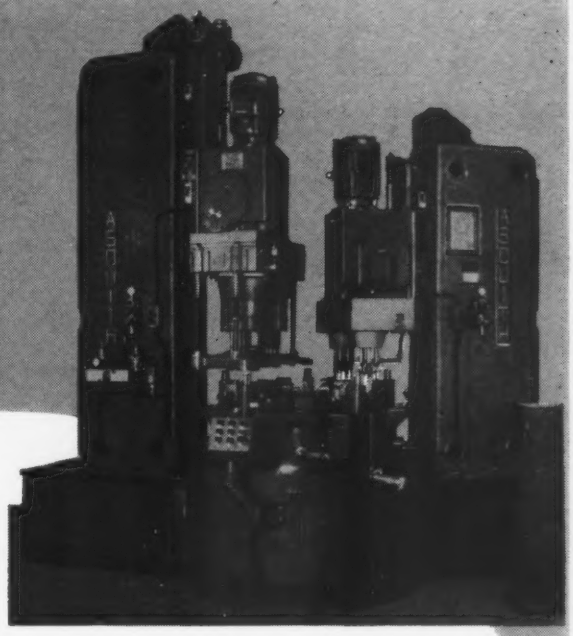
ASQUITH

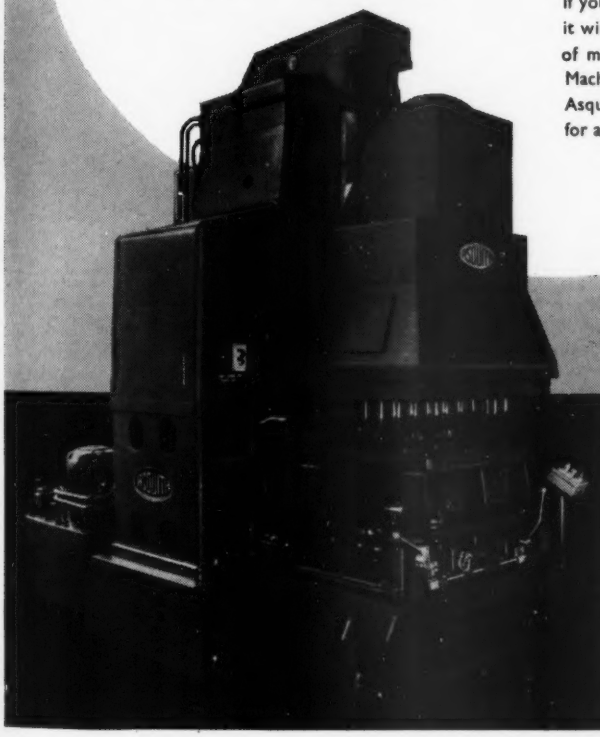
UNIT TYPE MACHINES

fully engineered for high-output production



Asquith Five Station Rotary Transfer Machine for drilling, reaming and tapping operations on a Vauxhall hub component.

Asquith Two Way Machine supplied to R. A. Lister Ltd., Dursley for the production of 6 cylinder Diesel crankcases.



Asquith Units from ½ h.p. upwards can be arranged as individual, multi-way, rotary transfer and in-line transfer machines for fast, automatic production. If you require large quantity output of components it will be worth investigating the possibility of machining them on an Asquith Unit Type Machine. Write today for details of the Asquith range of Unit Equipment or ask for a specialist to discuss your problem.

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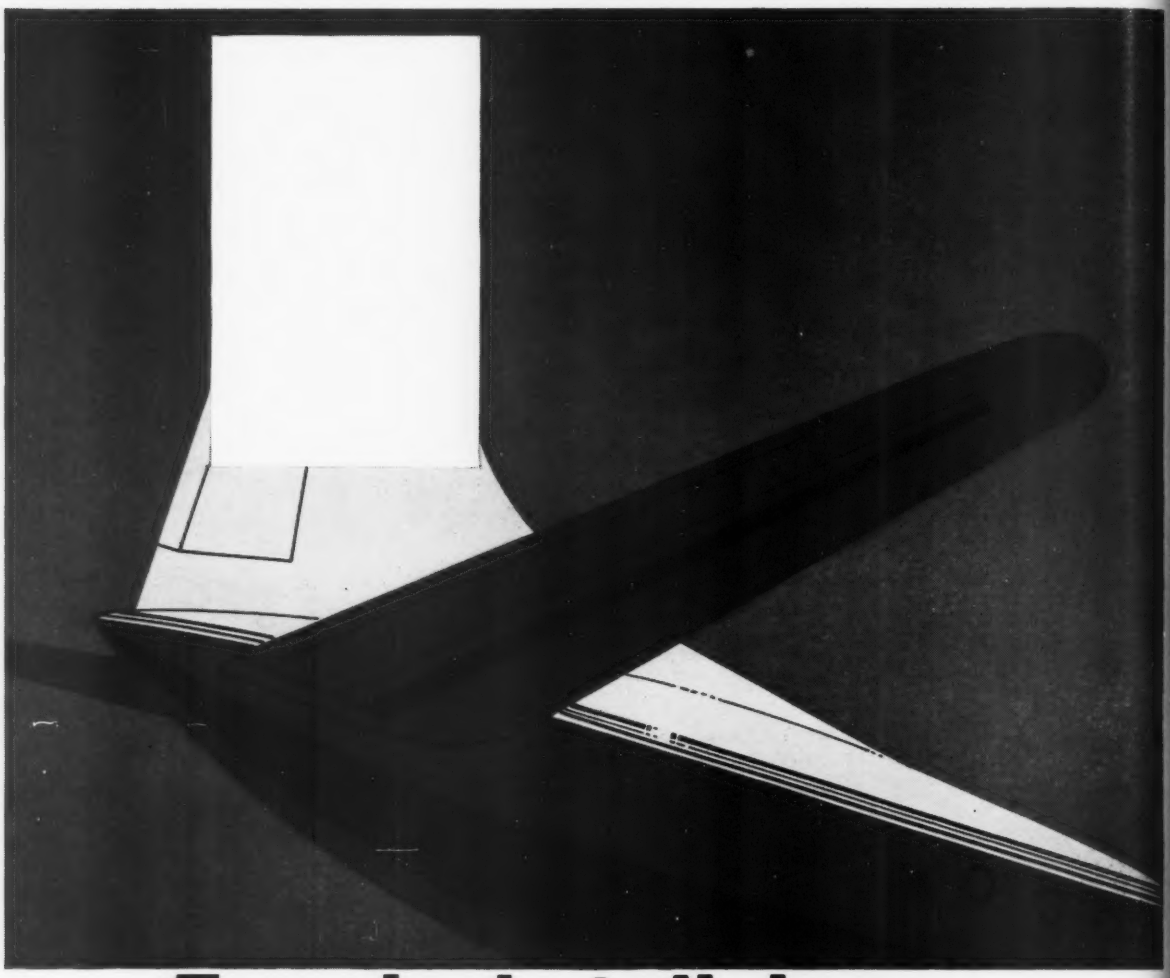
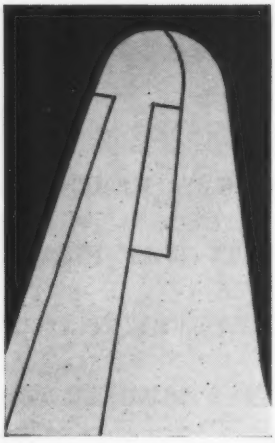


Tuesday's tailplane



There is no doubt that the tailplane will be there on Tuesday – or that every other part and sub-assembly will be available on the scheduled date.
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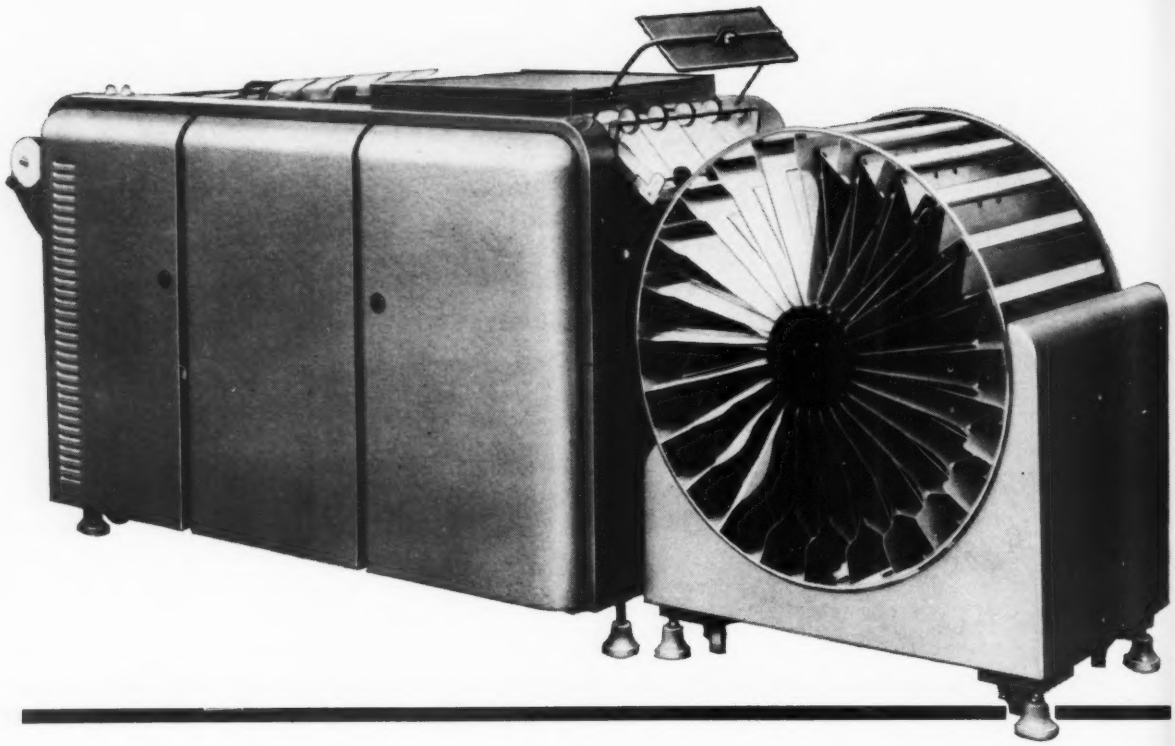

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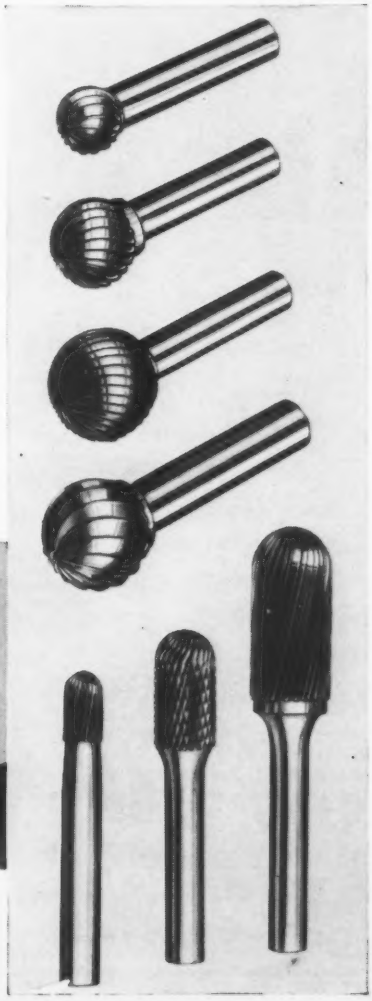

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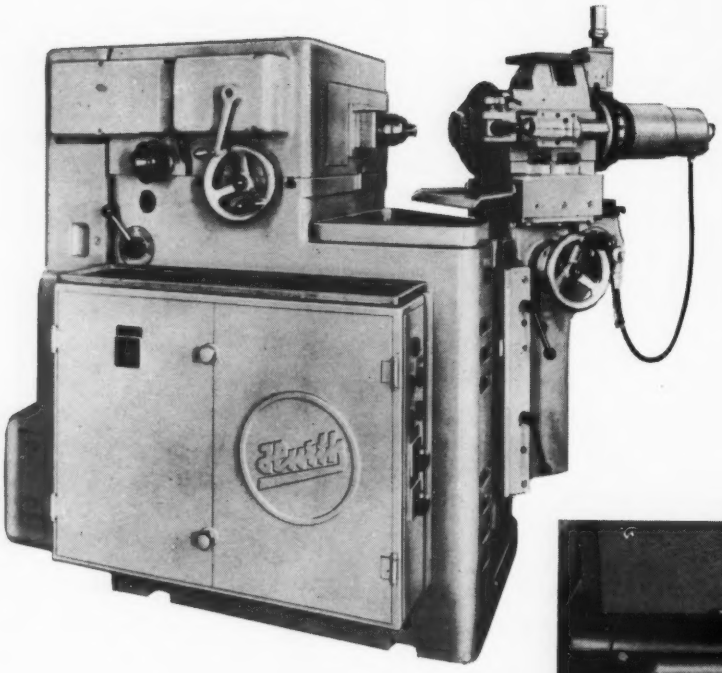

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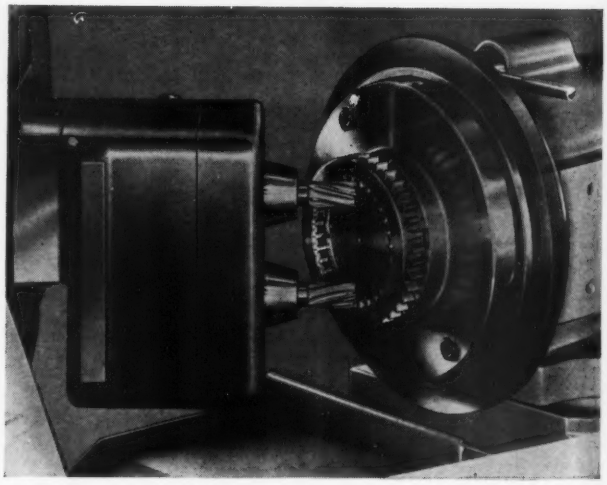

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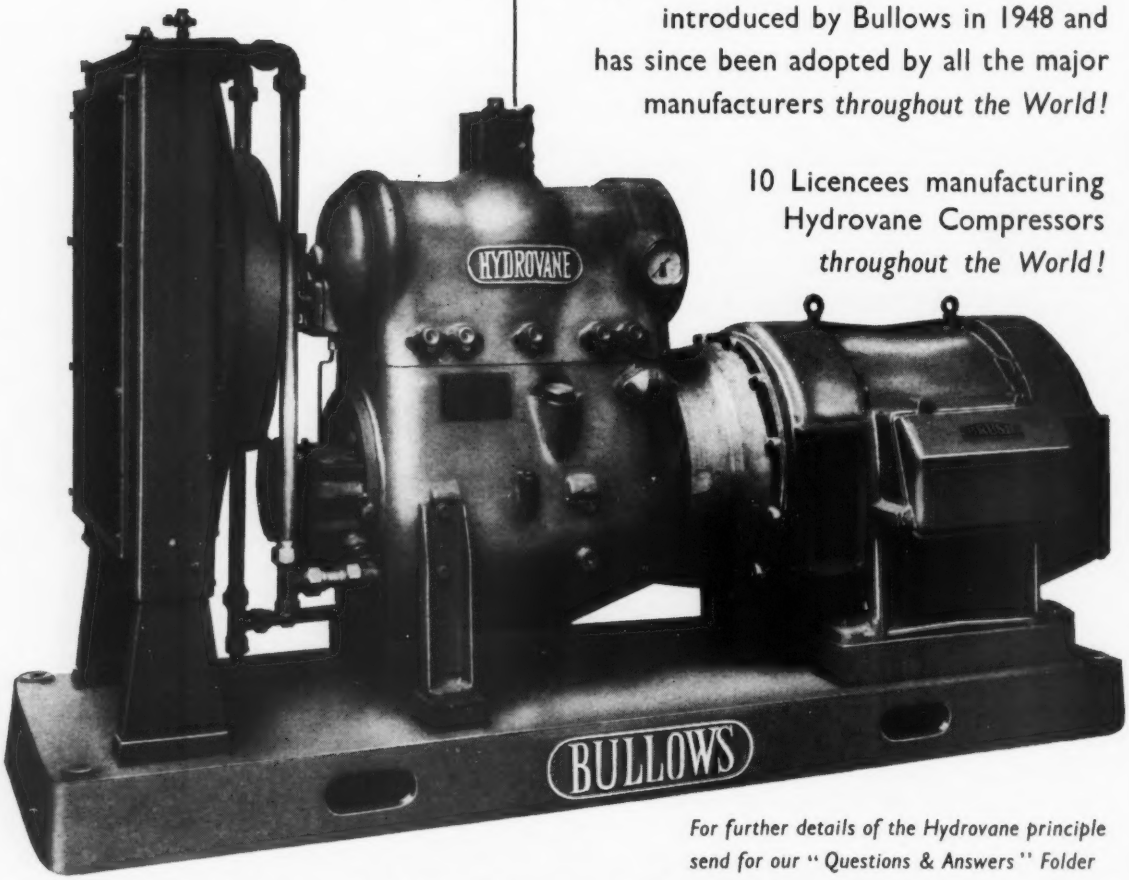
10 Licencees manufacturing Hydrovane Compressors *throughout the World!*



For further details of the Hydrovane principle send for our "Questions & Answers" Folder

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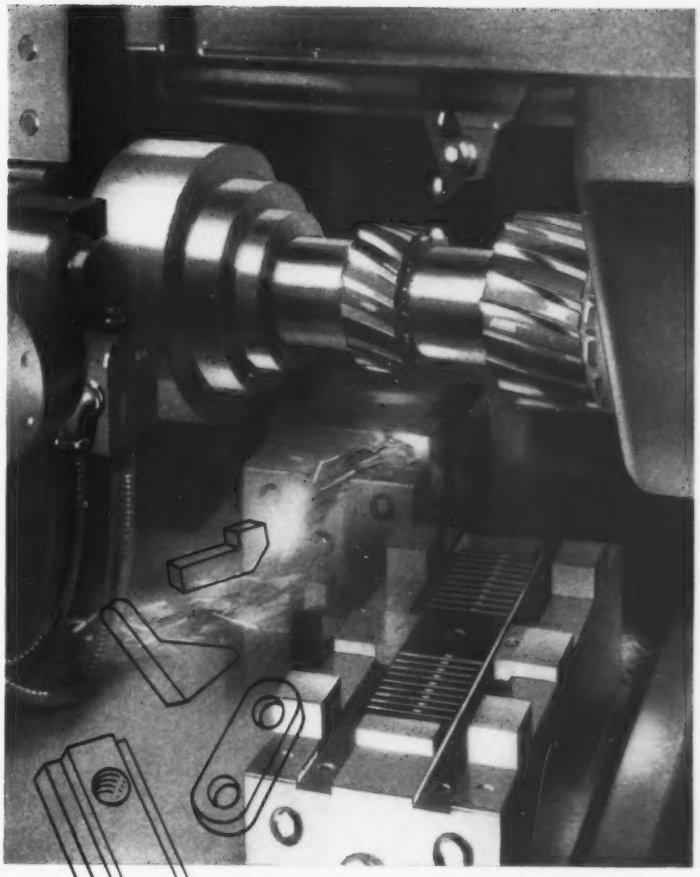

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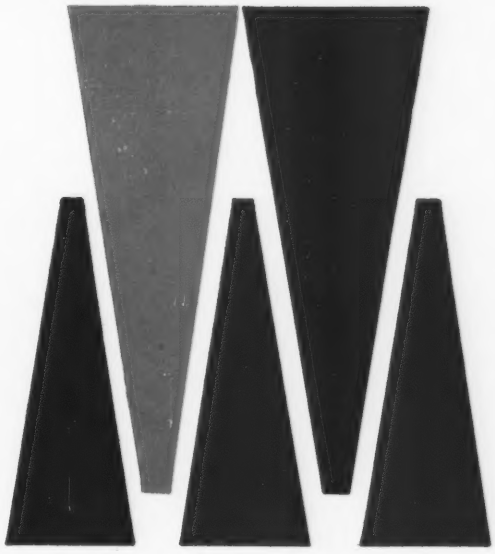

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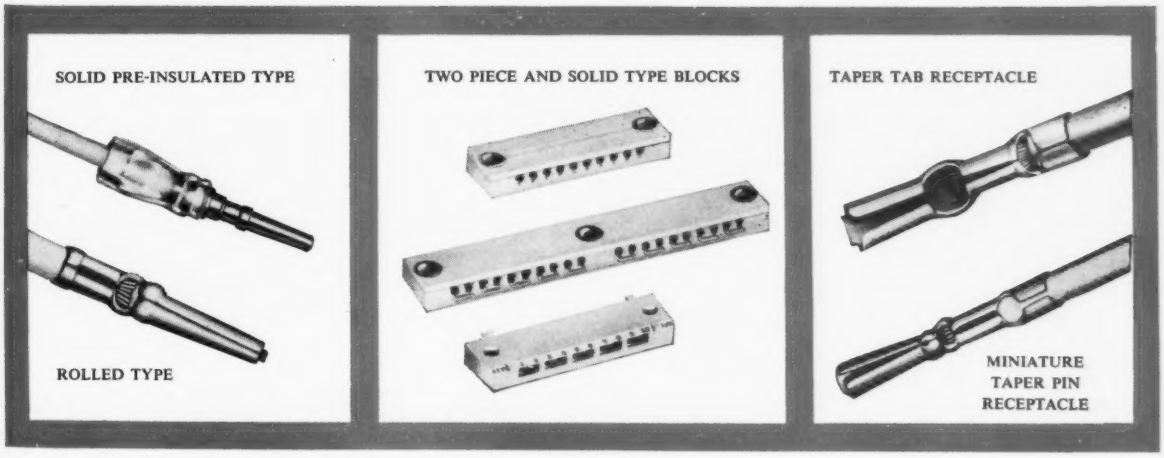

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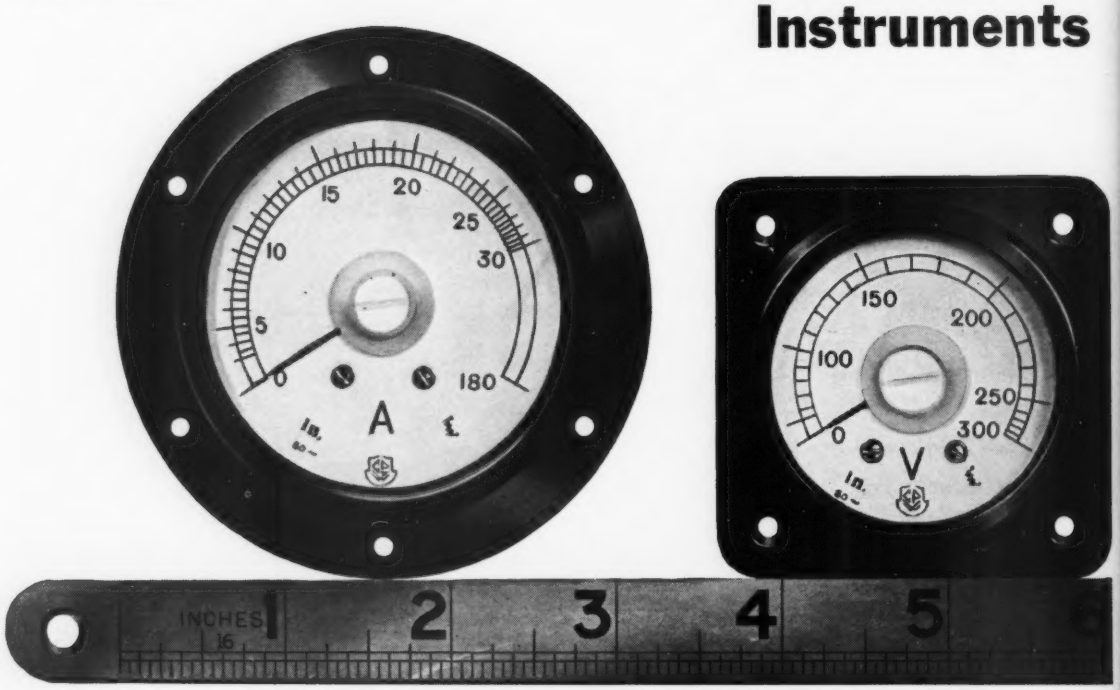

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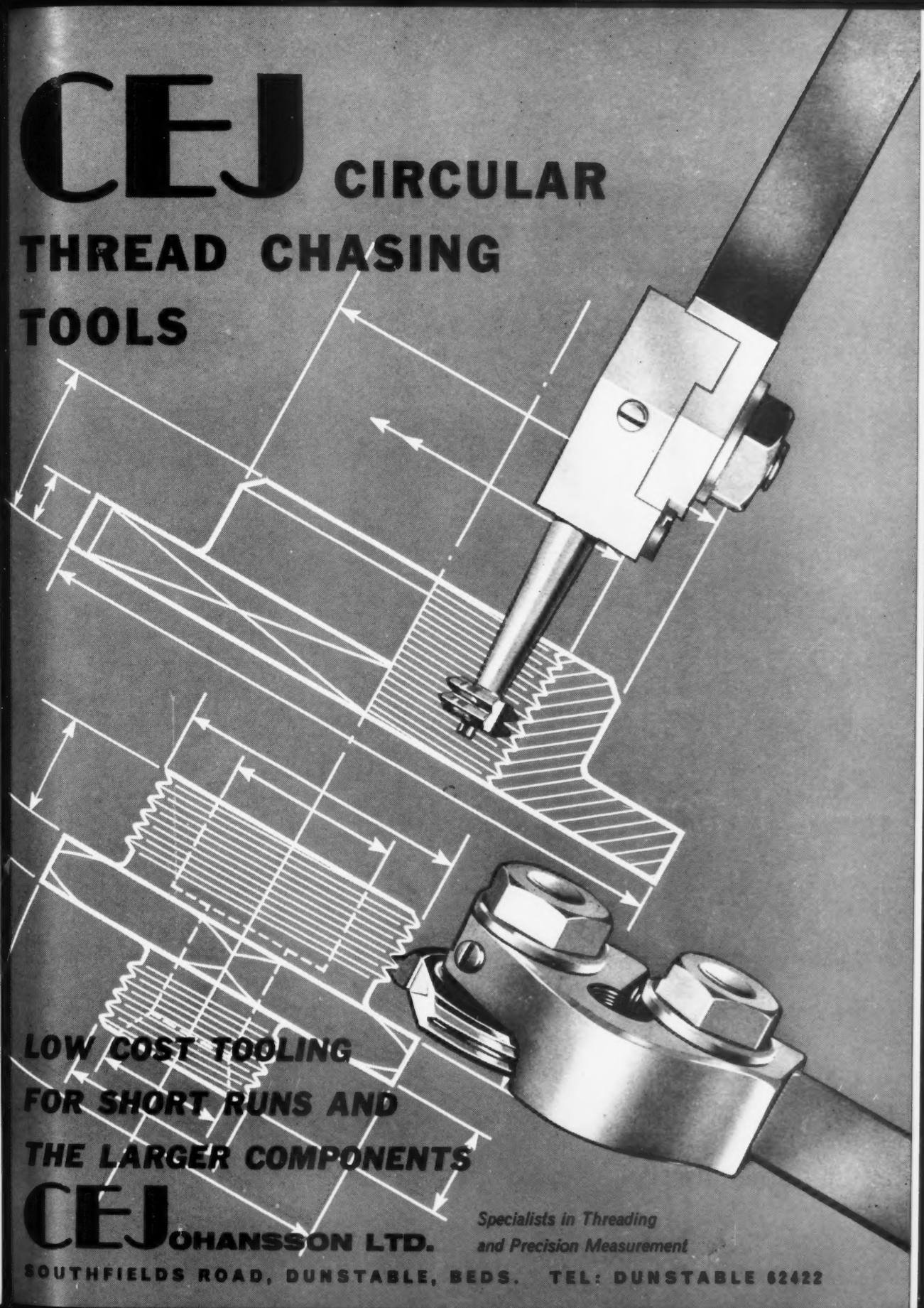

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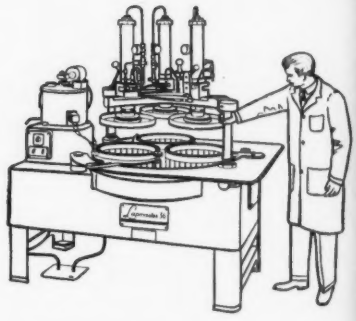

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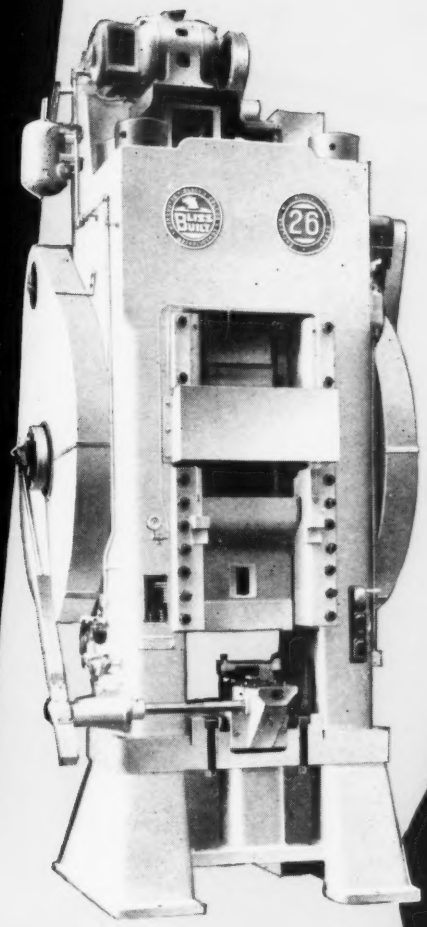

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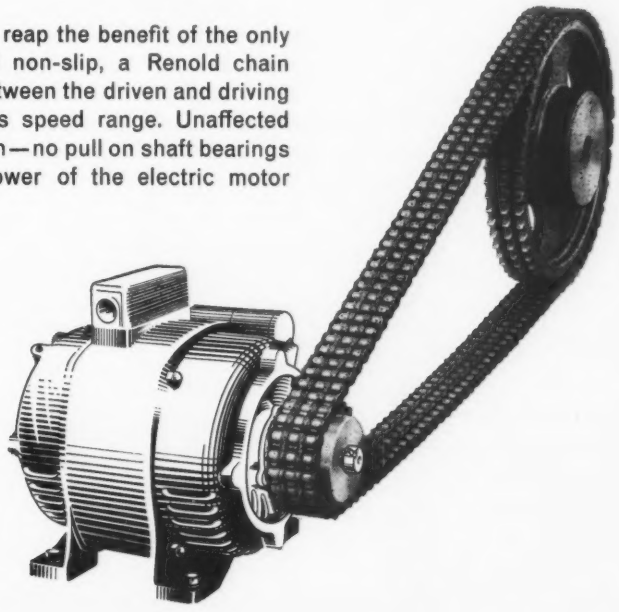

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Electrical Aids in Industry *Data Sheet* **No.18**

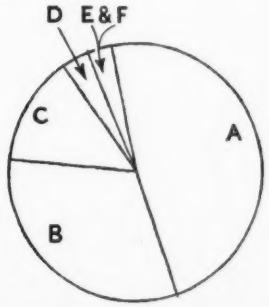
Factory Heating-1

The space heating of factories by electrical means can be achieved in a variety of ways which will be dealt with in the next Data Sheet.

Before deciding on any form of factory space heating—whether by means of electricity or not—it is as well to have clearly in mind all the components of the total annual running cost, and not merely the fuel cost, of the installation.

They are:

- **(A)** The cost of the fuel or the electricity,
- **(B)** Interest and depreciation on the capital cost of the installation,
- **(C)** Labour,
- **(D)** The cost of running auxiliary plant such as fans and pumps,
- **(E)** Maintenance,
- **(F)** Insurance.



In comparing fuel costs it should be borne in mind that electric heat is refined heat and has had all the fuss, bother and dirt of the conversion of fuel into heat taken out at the generating station.

In arriving at the true figures for capital cost and depreciation, maintenance, and insurance, those connected with such items as boilerhouse, chimney, fuel store and access road should be included; labour costs should include such tasks as ash disposal. None of these items occurs when electricity is used, although space will be required for the electric boiler and storage vessels in the case of the type (h) following.

Electricity provides the ideal answer to the requirements of the Clean Air Act, the impact of which has introduced an important new factor during the last few years.

CUT HERE

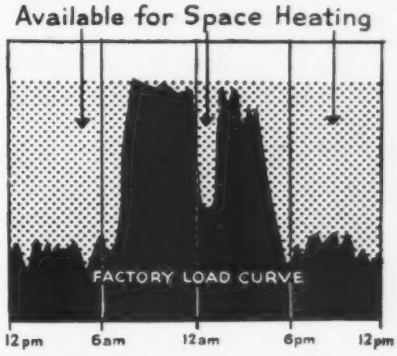
The following list gives the main types into which electric heating installations fall:

- (a) High temperature ("infra-red") overhead heaters operating at near red heat.
- (b) Medium temperature panels operating at surface temperatures of 400° to 600°F.
- (c) Extended surfaced heating in the shape of floorwarming operating at temperatures up to 80°F.
- (d) Oil and water filled radiators.
- (e) Tubular heaters.
- (f) Unit heaters.
- (g) Storage block heaters.
- (h) Electric boilers and water heaters operating in conjunction with hot water radiators or panels either with or without water storage.

All these methods of electric heating can be divided into two distinct classes:

- (a) Those that utilise electricity during "off-peak" hours and store the heat so generated for use at a later period.
- (b) Those that use electricity whenever the heating system is in use (i.e. direct electric heaters).

The use of a heat storage system in a small works on a block tariff takes advantage of the lower tariff offered for an off-peak supply, and in the larger factory on a Maximum Demand tariff means that the heating load will not incur any M.D. charge.



Alternatively there may be cases where the use of direct electric heaters can be integrated with other factory loads in such a way that they are not used during the factory peak periods and will thus incur no additional M.D. charge.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2.

Excellent reference books on the industrial and commercial uses of electricity and reprints of articles and papers are available. An example is "Higher Industrial Production with Electricity" (price 8/6 each or 9/- post free).

E.D.A. also have available on free loan in the U.K. a series of films on the industrial uses of electricity. Film and Book catalogues and Publications List sent on request.

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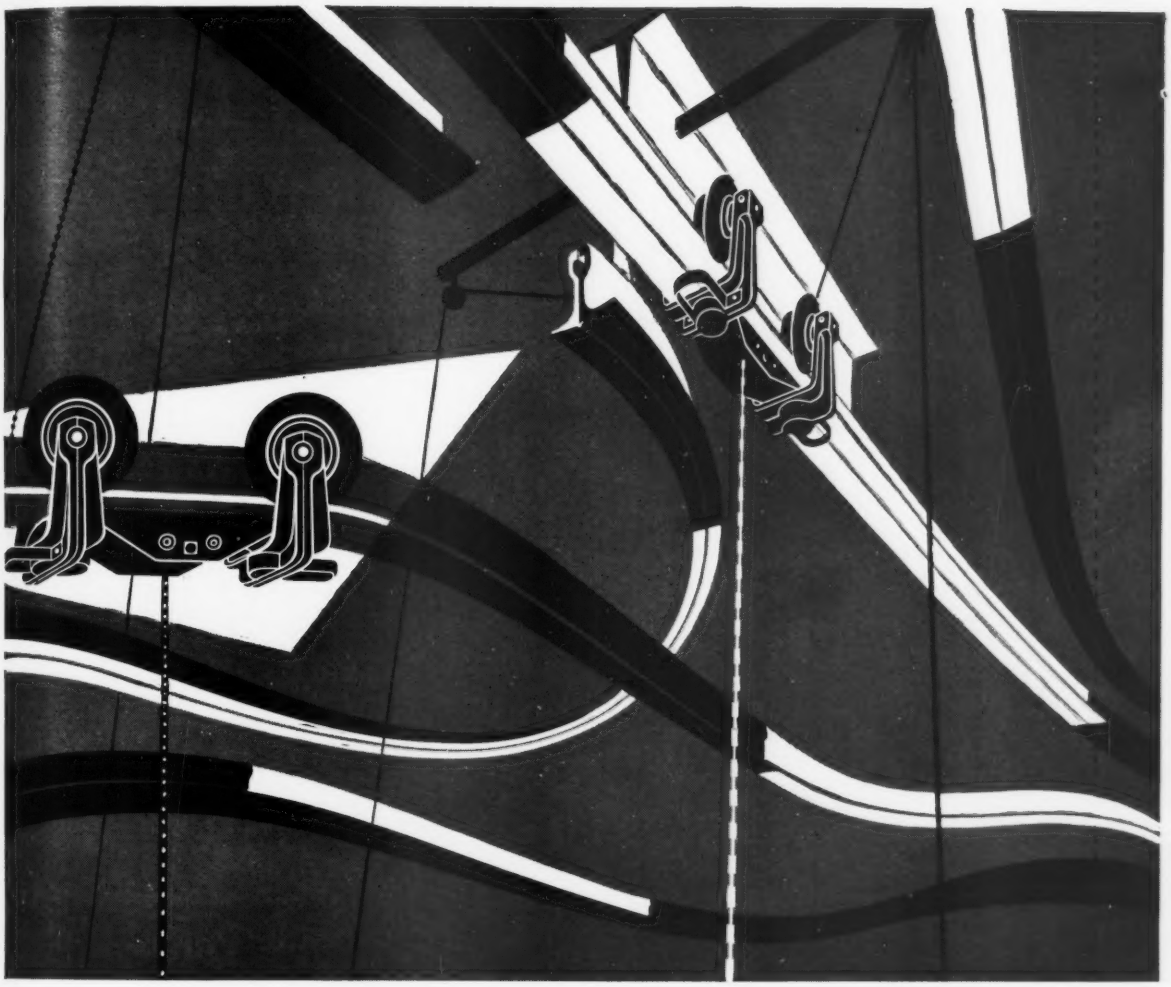

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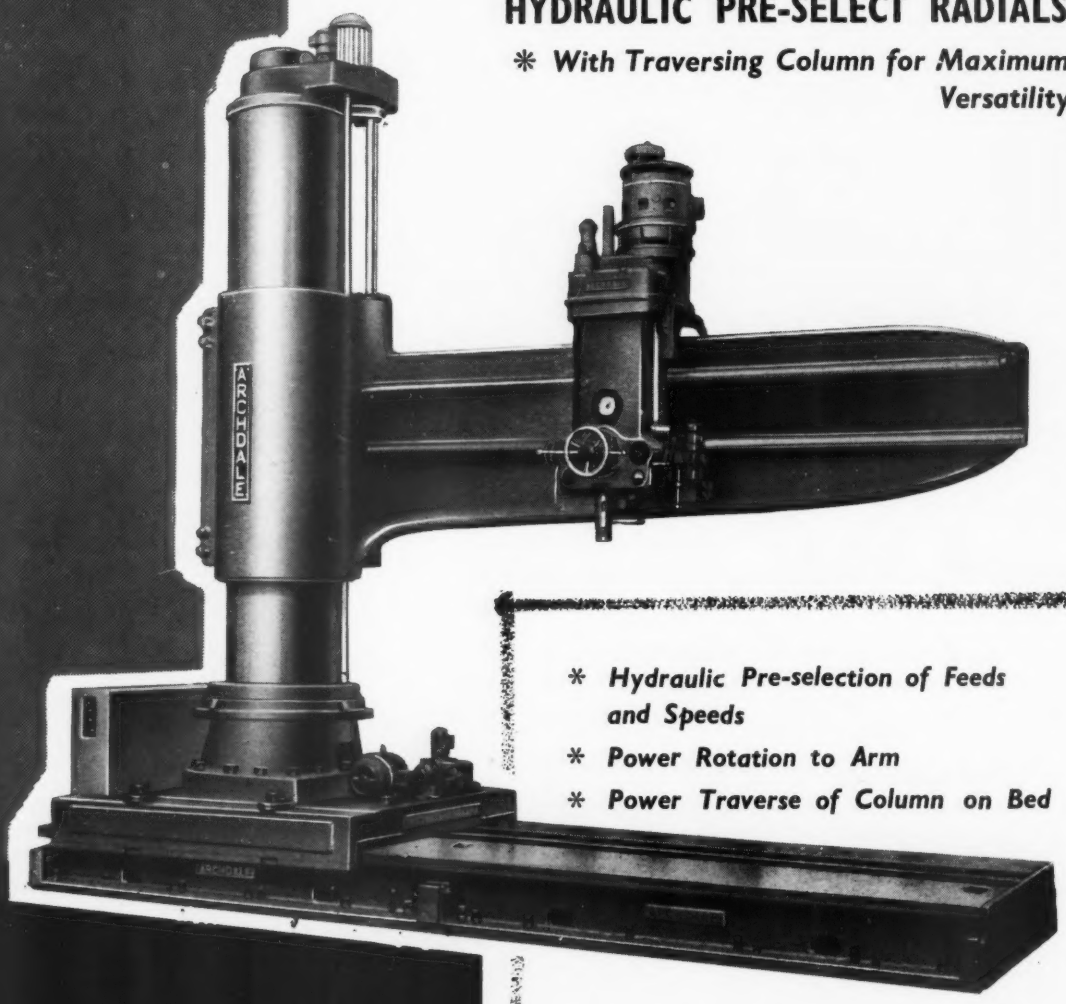

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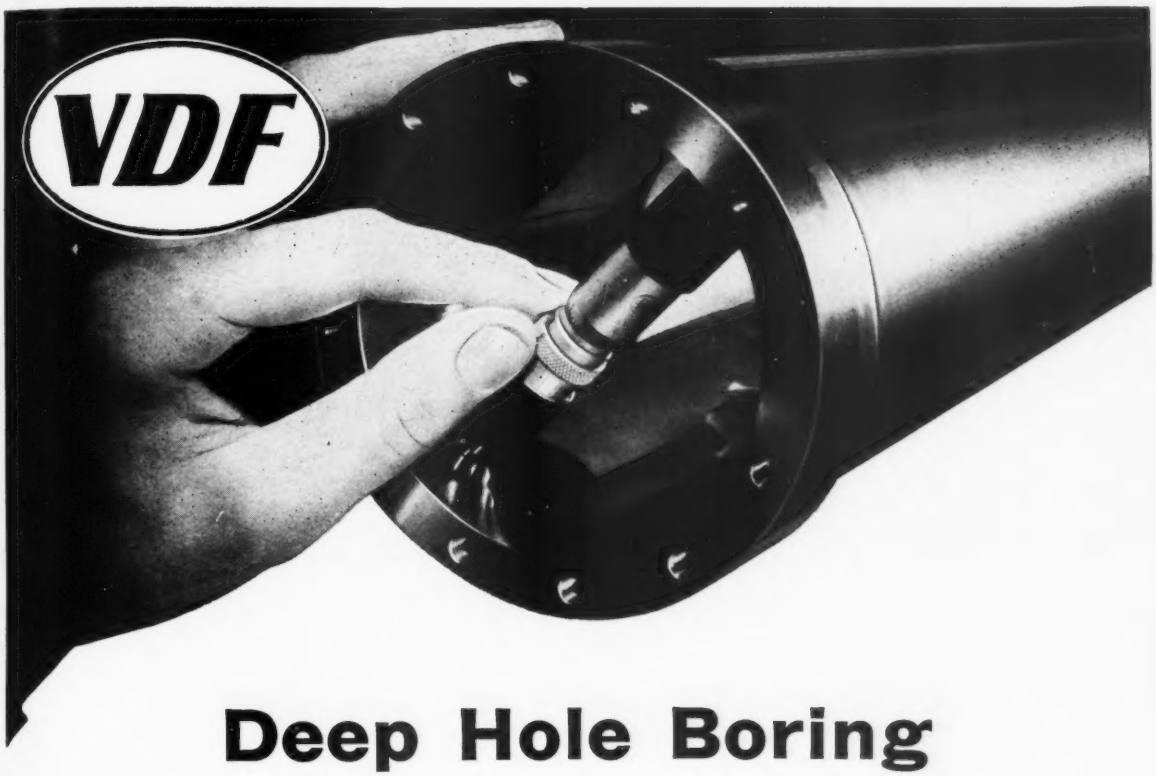
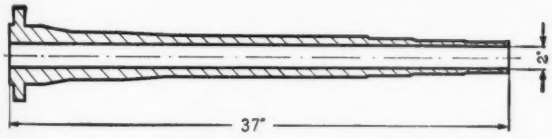
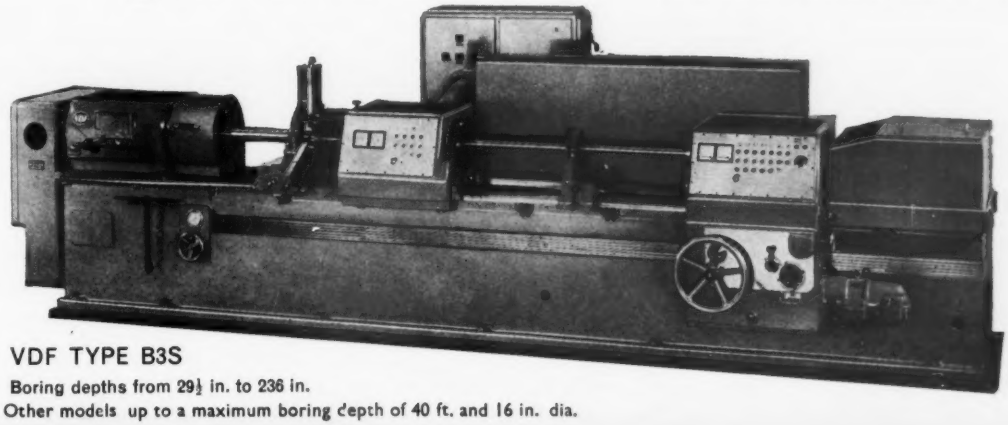


Deep Hole Boring



- Spindle Speed: 710 R.P.M.
- Feed Rate: .0063 in./rev.
- Material: EN 9.
- Floor to Floor Time: 10.5 mins.

The work spindle illustrated is machined on a V.D.F. Deep Hole Boring Machine using the solid boring method and central chip disposal. The maximum axial deviation is .0039 in. over the length of 37 in., with a surface finish of 5-10μ.



VDF TYPE B3S

Boring depths from 29½ in. to 236 in.
Other models up to a maximum boring depth of 40 ft. and 16 in. dia.

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The large Compressor illustrated is typical of our 'Comoblok' range of machines. This range covers capacities from 500—2,000 c.f.m. These machines are of the double-acting crosshead type, and are suitable for pressures up to 50 p.s.i.g. single stage, and 150 p.s.i.g. two stage. They are remarkable for their low power consumption and compact design. Send for Leaflet No. T29.

The machine alongside is one of our Oil-free Range. These are available in capacities from 100 to 2,000 c.f.m., and at all pressures up to 150 p.s.i.g. They are specifically designed to deliver uncontaminated air, and have many special features incorporated which make them unique in this field of Compressors. Send for Leaflet No. T31.

The two smaller machines shown illustrate our 'Uniblok' and 'Twinblok' Range, and cover capacities of from 50 to 400 c.f.m. at all pressures up to 120 p.s.i.g. These are of the single stage, single acting type, styled to give a neat appearance and are unrivalled for their low maintenance and space saving features. Send for Leaflet No. T19.

Tilghman's have a complete range of Vacuum Pumps to offer in displacements from 50—2,500 c.f.m., and are capable of drawing 28" Hg. on a 30" Hg. barometer.

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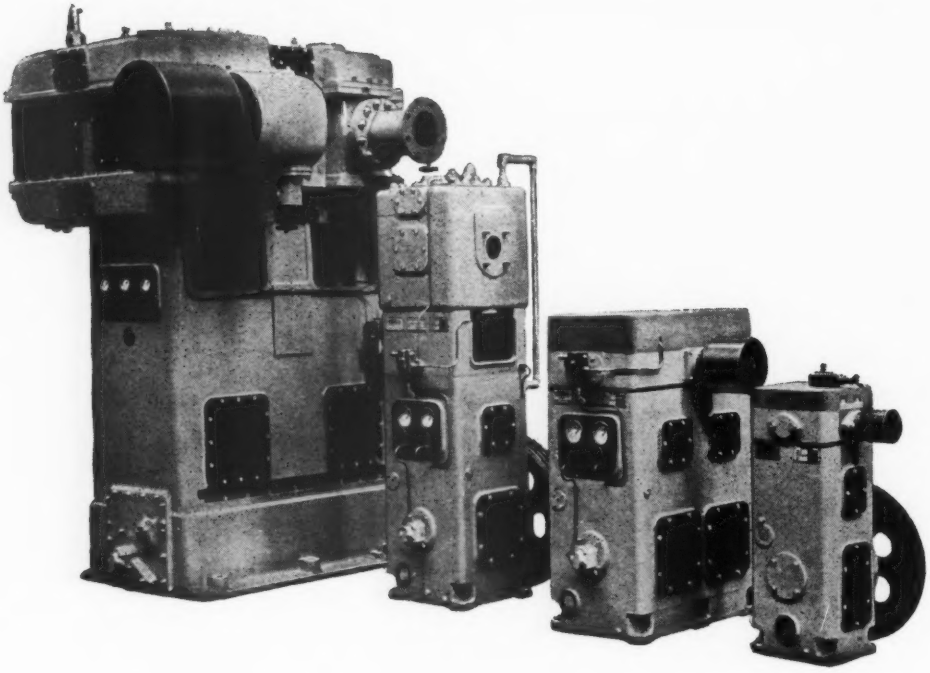

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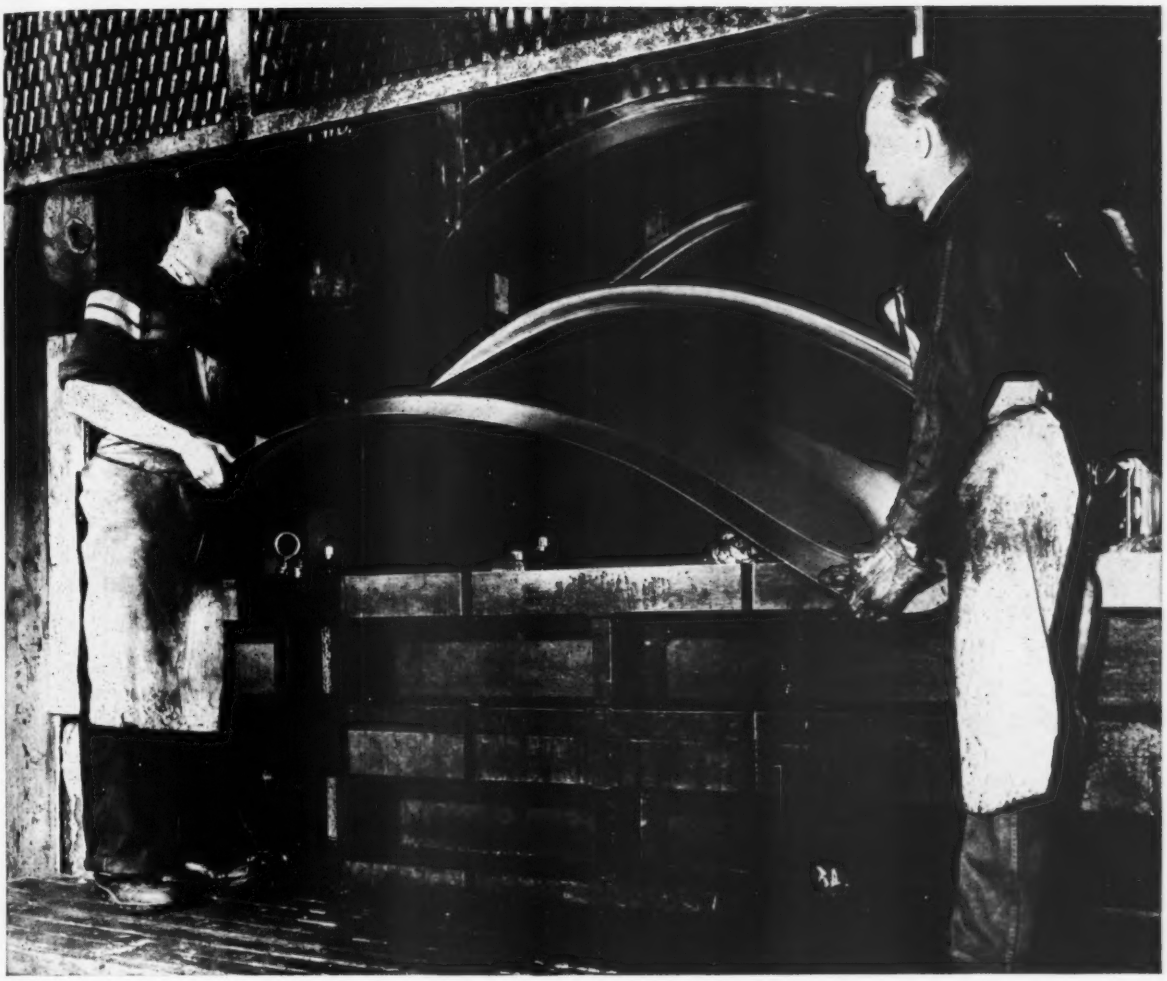

Photograph by courtesy of Messrs. A. V. Roe & Co. Ltd.

In the short run, too

It is not only in the long run that Araldite proves so economical. For short runs, calling for tools which can be made quickly and cheaply, Araldite epoxy resins offer many advantages. These include: high strength and dimensional stability; resistance to wear and freedom from deterioration; excellent adhesion to many materials, facilitating bonding and the use of fillers or metal inserts; ease of manufacture from moulds of many materials; ease of modification in the event of change of design; suitability for making tools of any size. For the past ten years, Messrs. A. V. Roe & Co. Ltd. have used Araldite to manufacture large press tools for aircraft production. The photograph shows a freight door-frame measuring 84″ x 60″ x 4″ for the new Avro 748. It is formed in 14 s.w.g. light alloy by an Araldite-faced double action draw tool, which has already produced over 100 pressings.

May we send you our booklet 'Araldite Resins for Tooling'?

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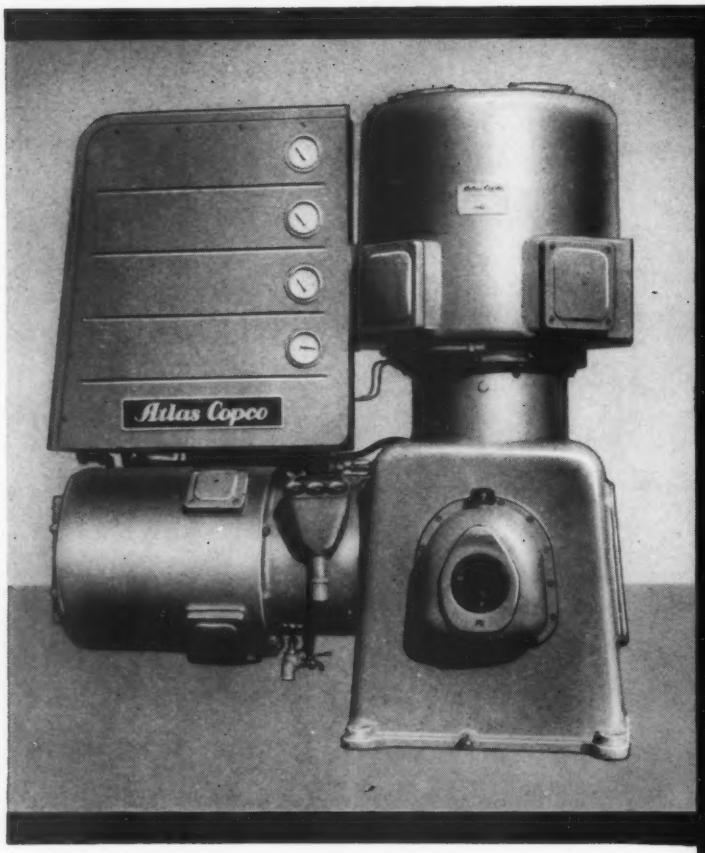

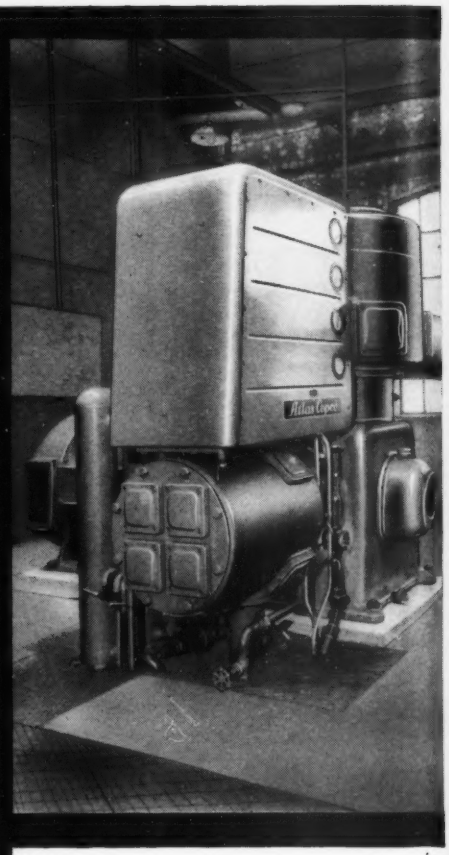

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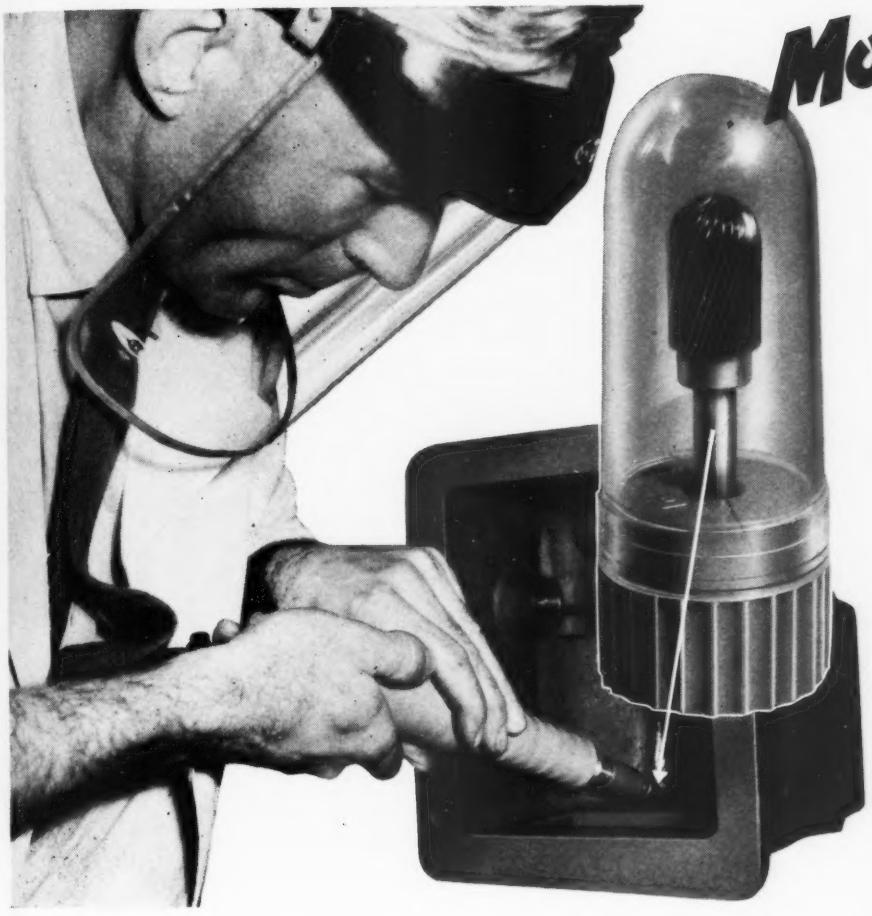

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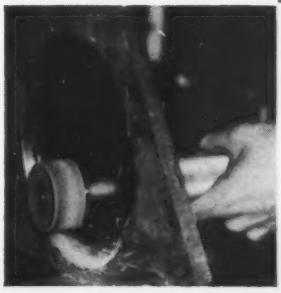

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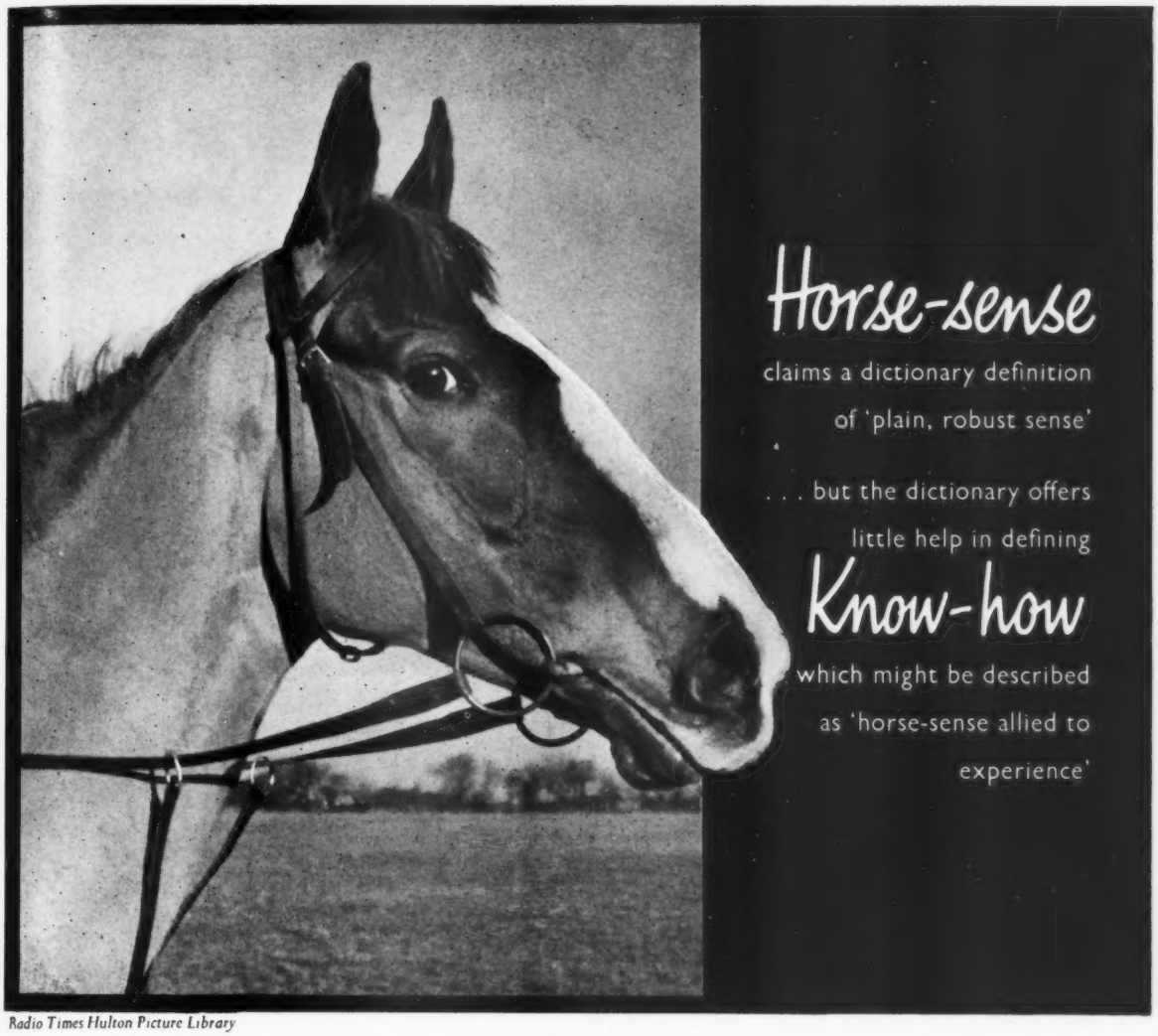

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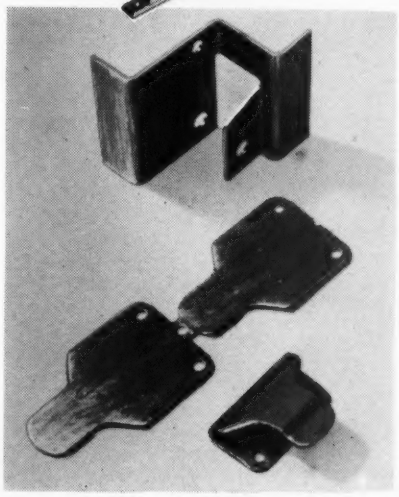

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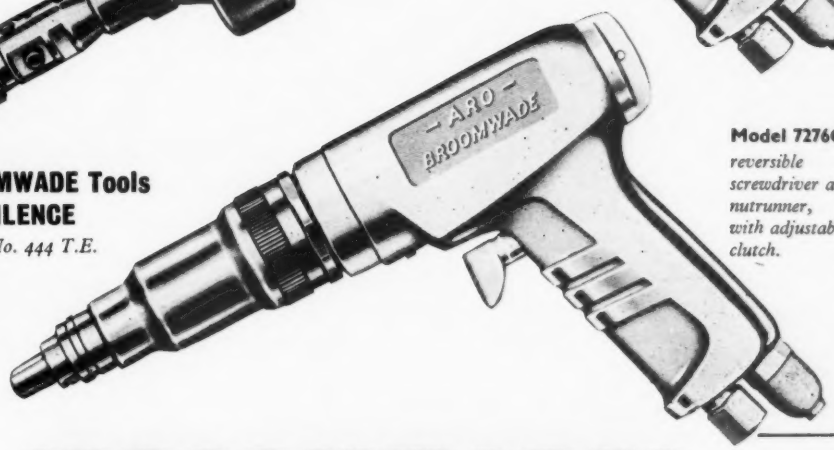

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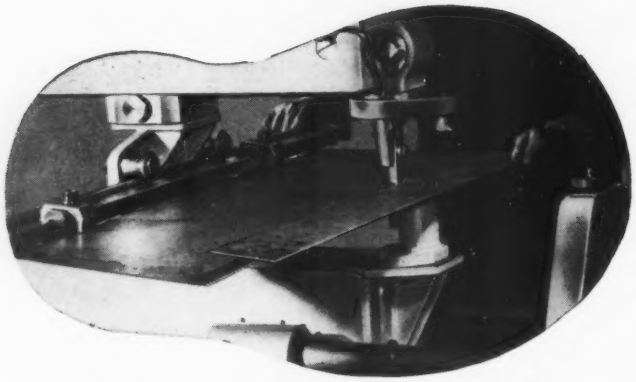

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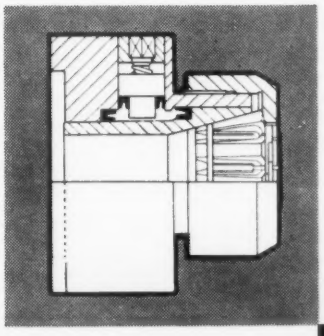

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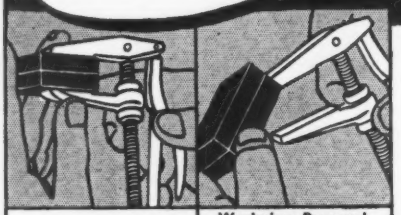
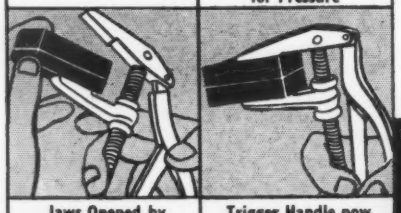


Lower Jaw Adjusted to Correct Distance

Workpiece Removed, Lower Jaw Adjusted for Pressure



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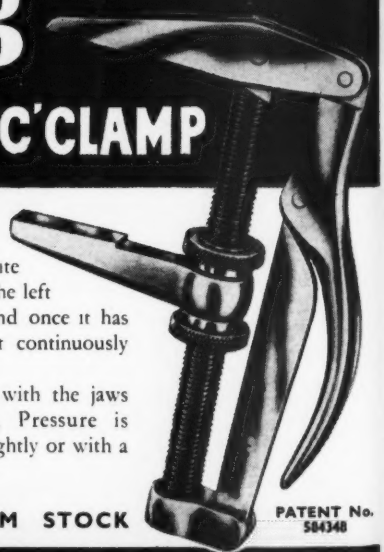

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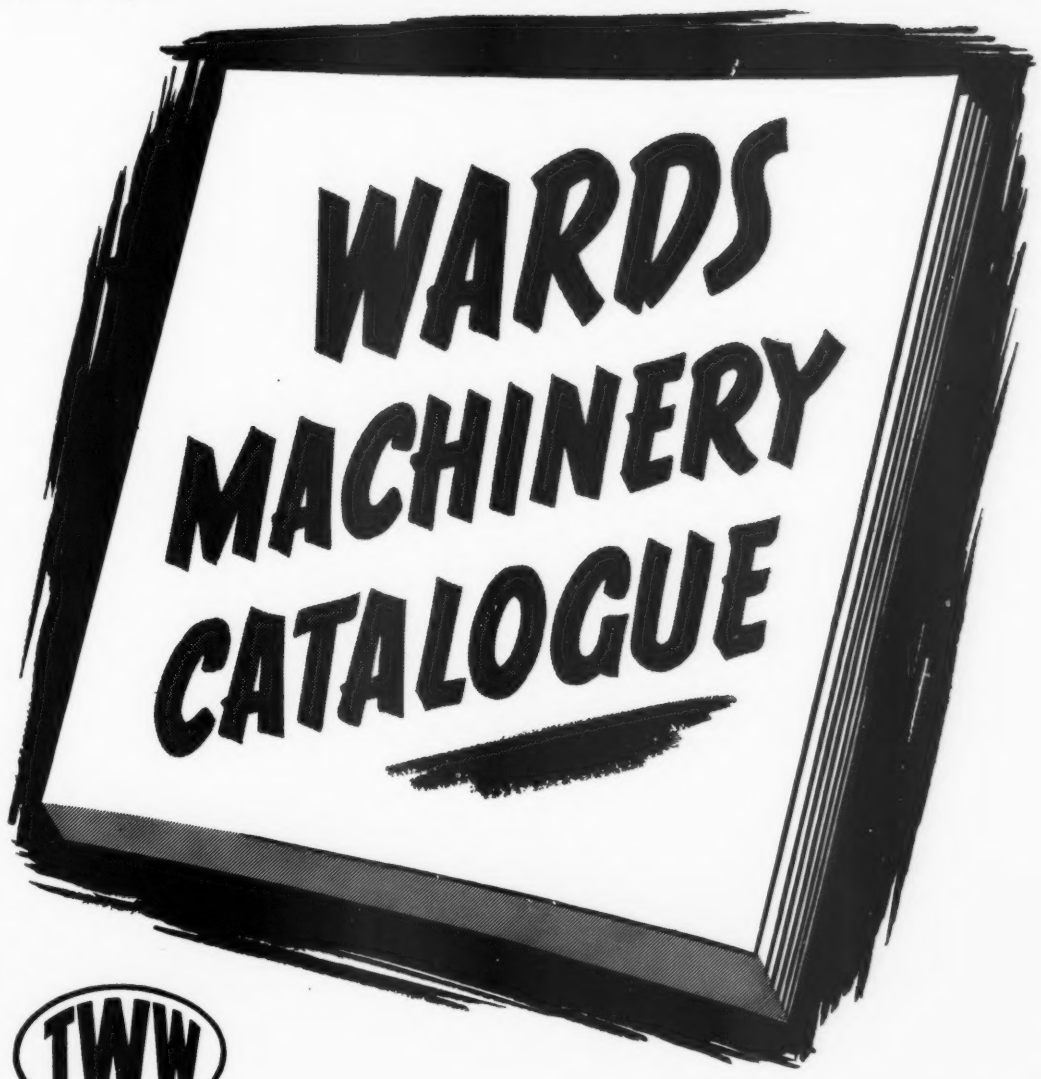

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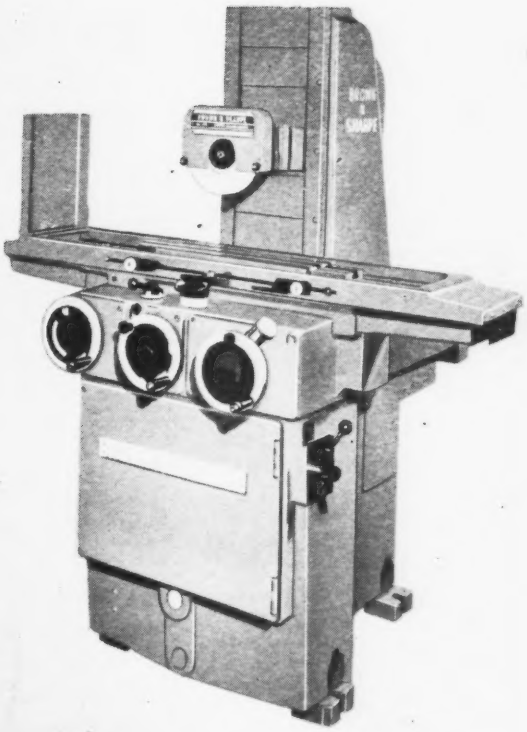

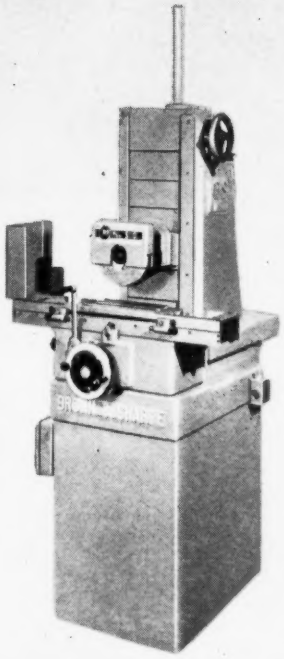

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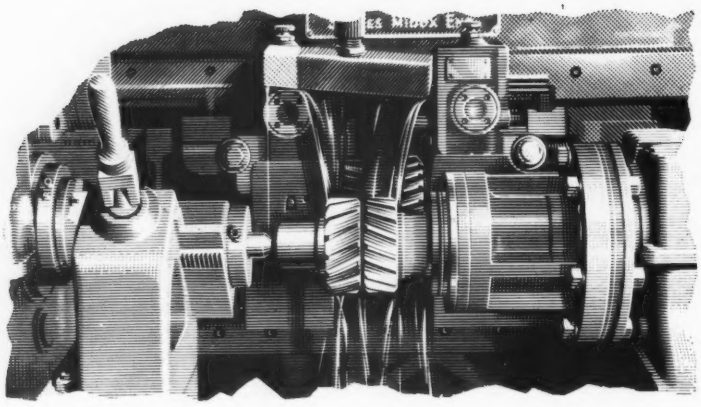

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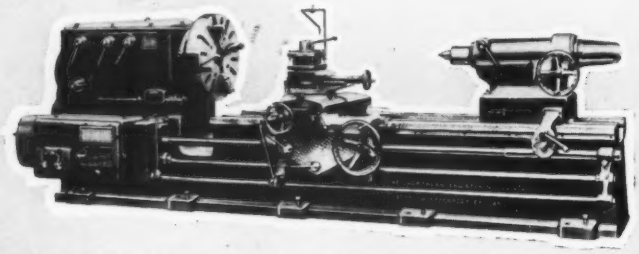

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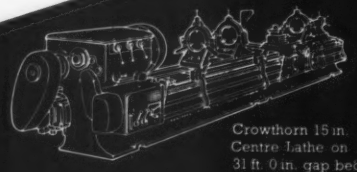

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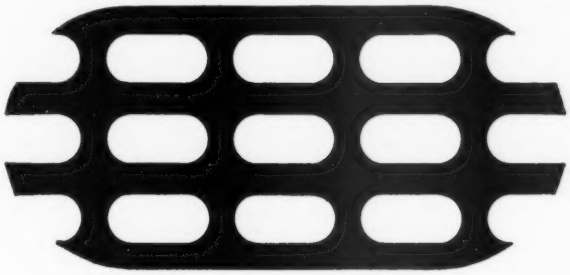

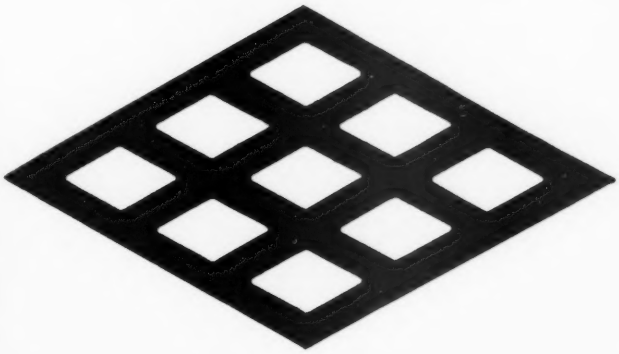

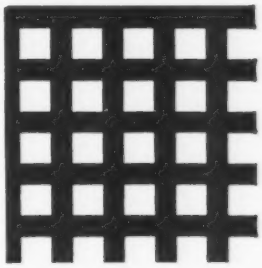

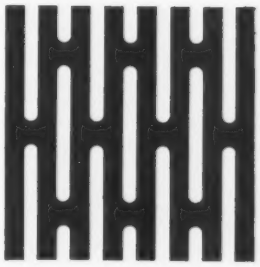

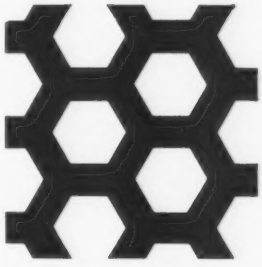

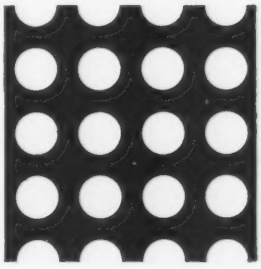

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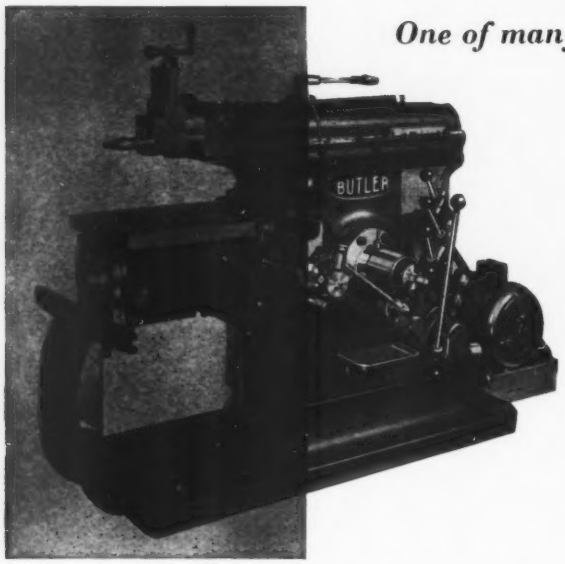

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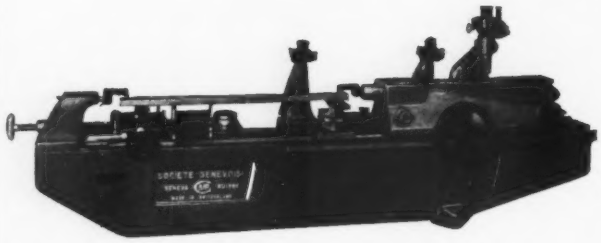

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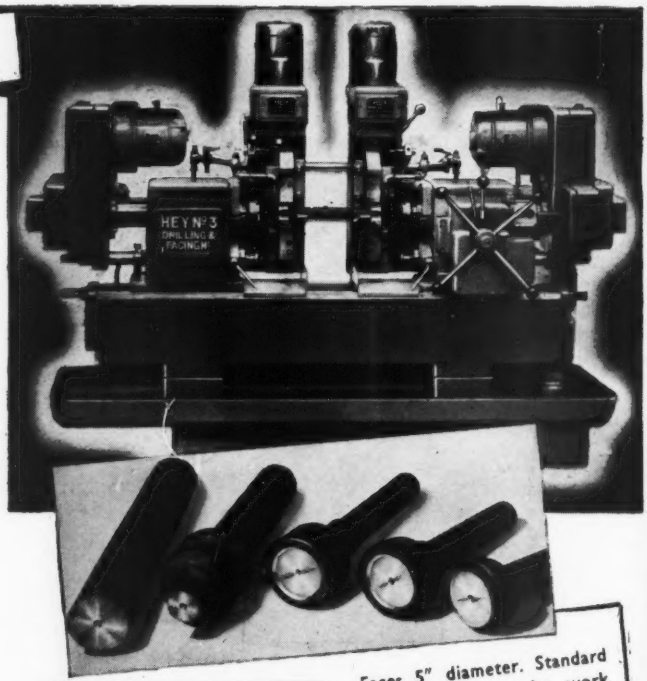

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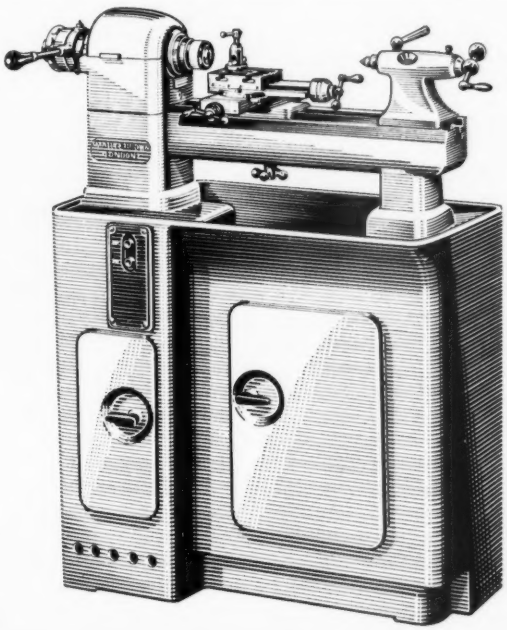

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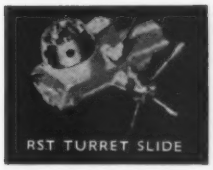
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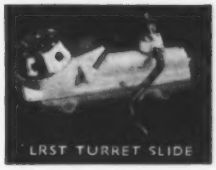
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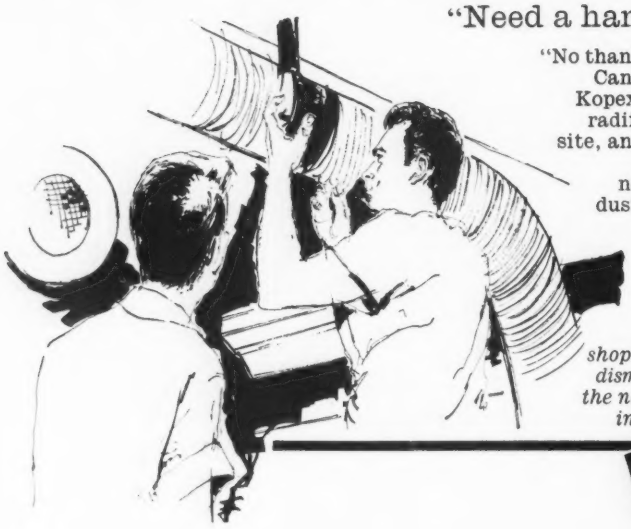

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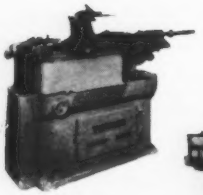

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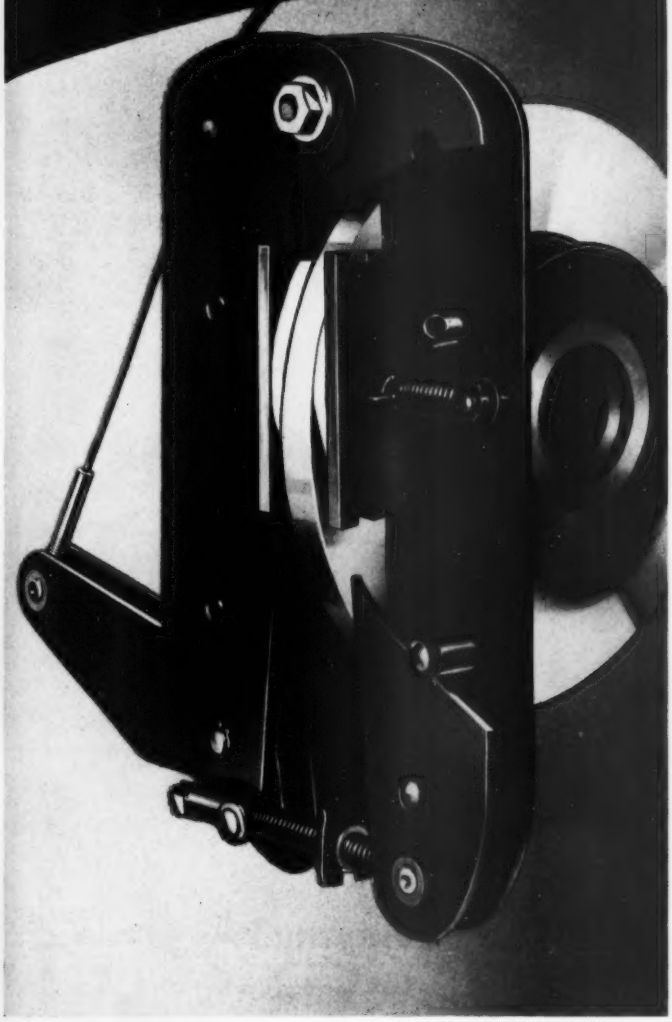

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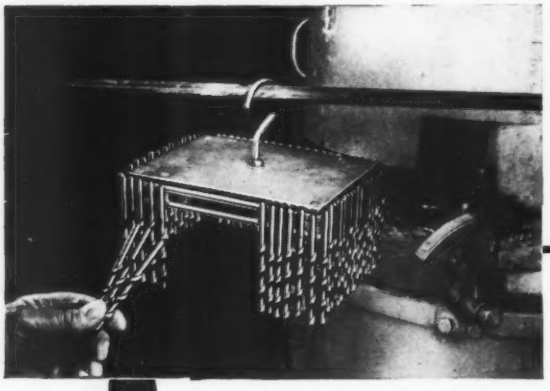

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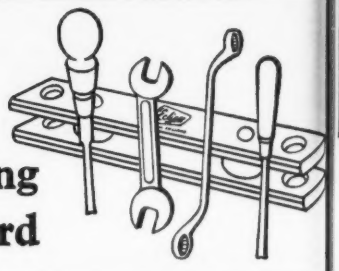

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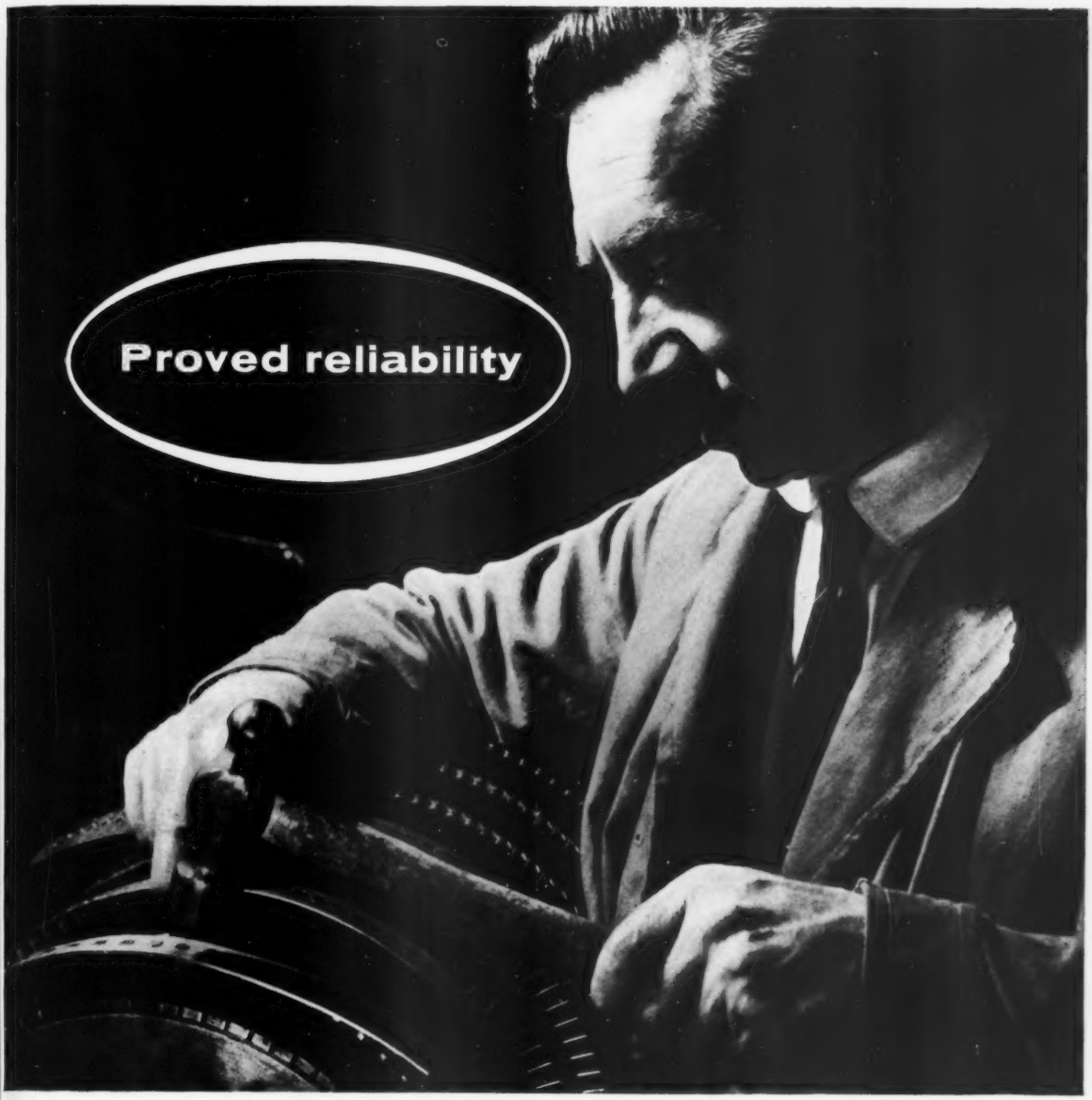

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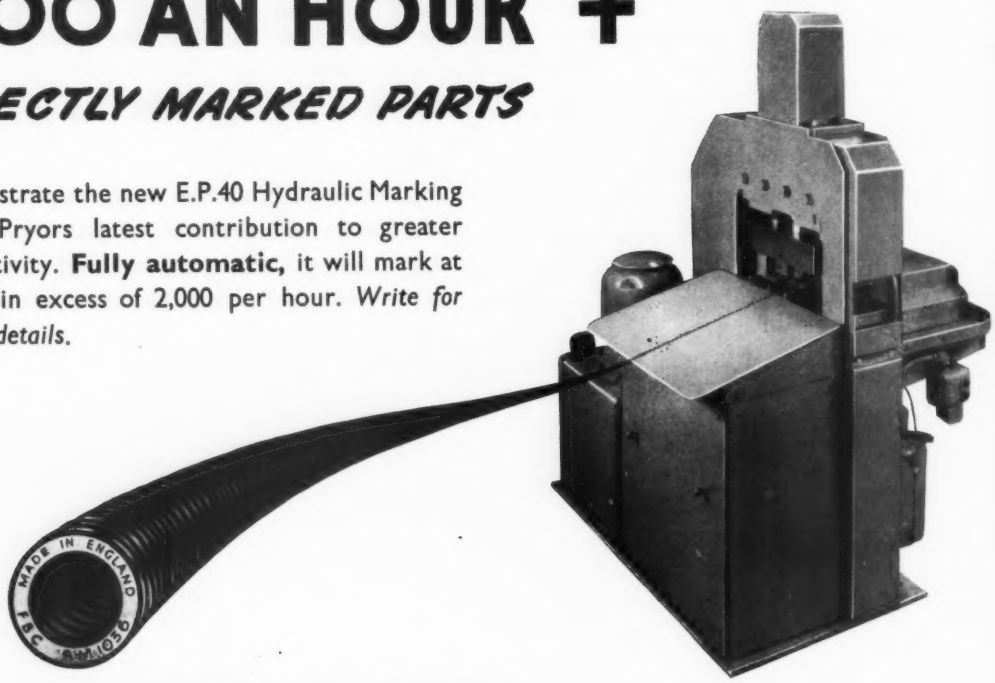

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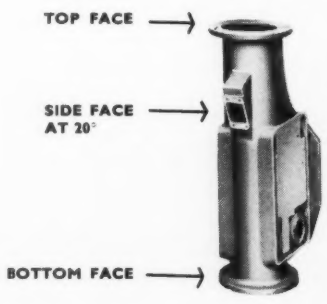
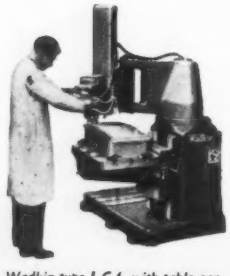


The fastest means of milling light alloys

TABLE CANTS TO THE VERTICAL ON BOTH LEFT AND RIGHT-HAND SIDES

Wadkin Articulated Arm Router, L.C.6, machining aluminium selector bodies for 5½" diameter pneumatic tube system. Photographs by courtesy of the Lamson Engineering Co. Ltd., London, N.W.10.



Wadkin type L.C.6, with table canted 10° to the right to present an inclined top face.

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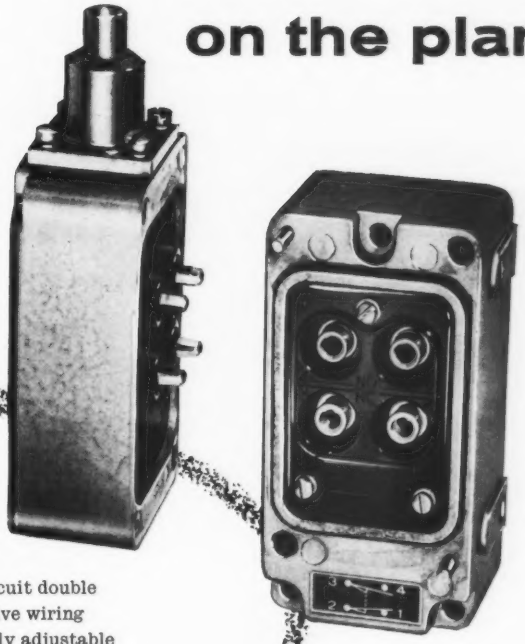

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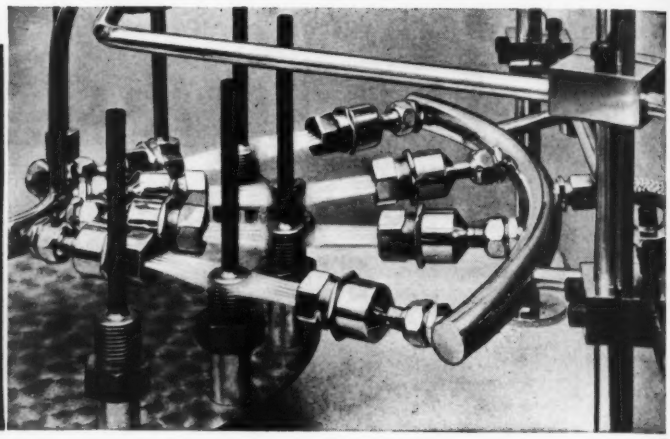

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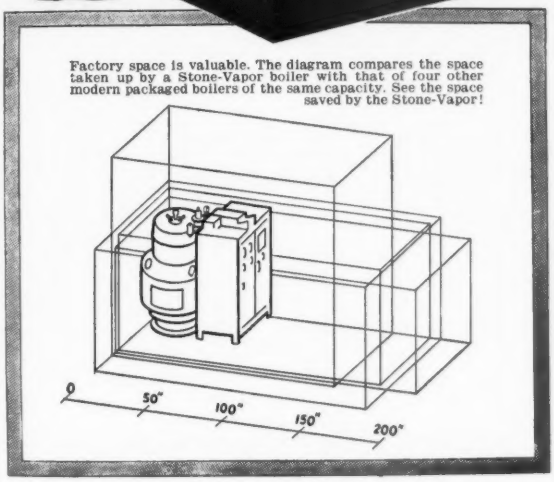

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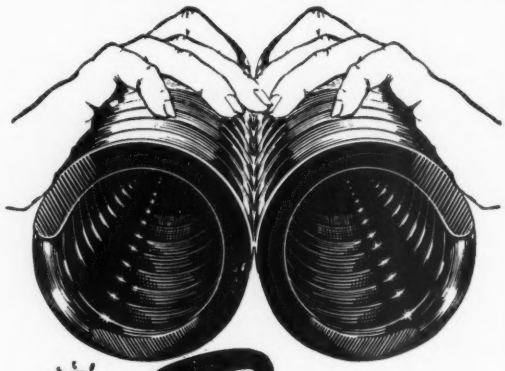
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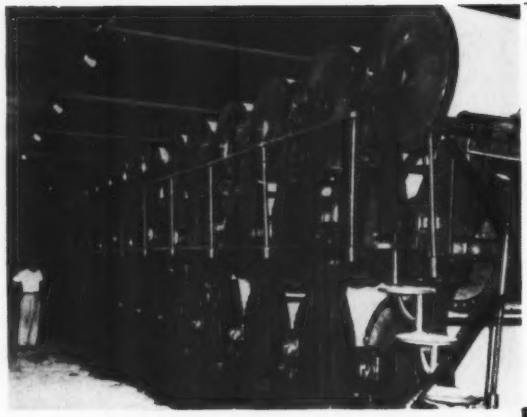

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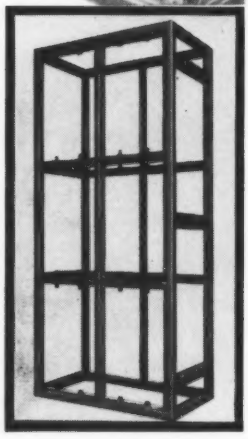

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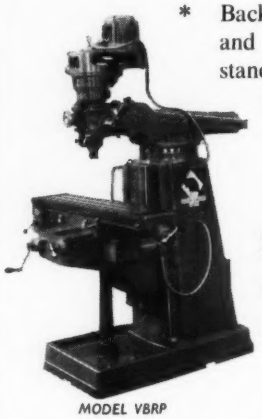

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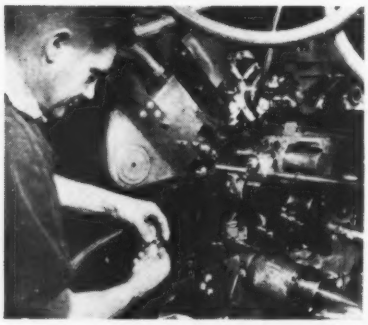

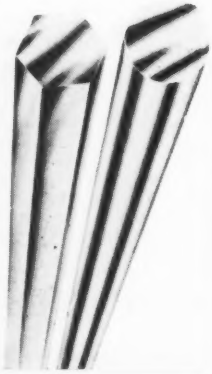

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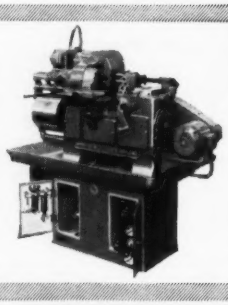

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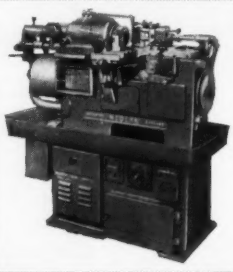

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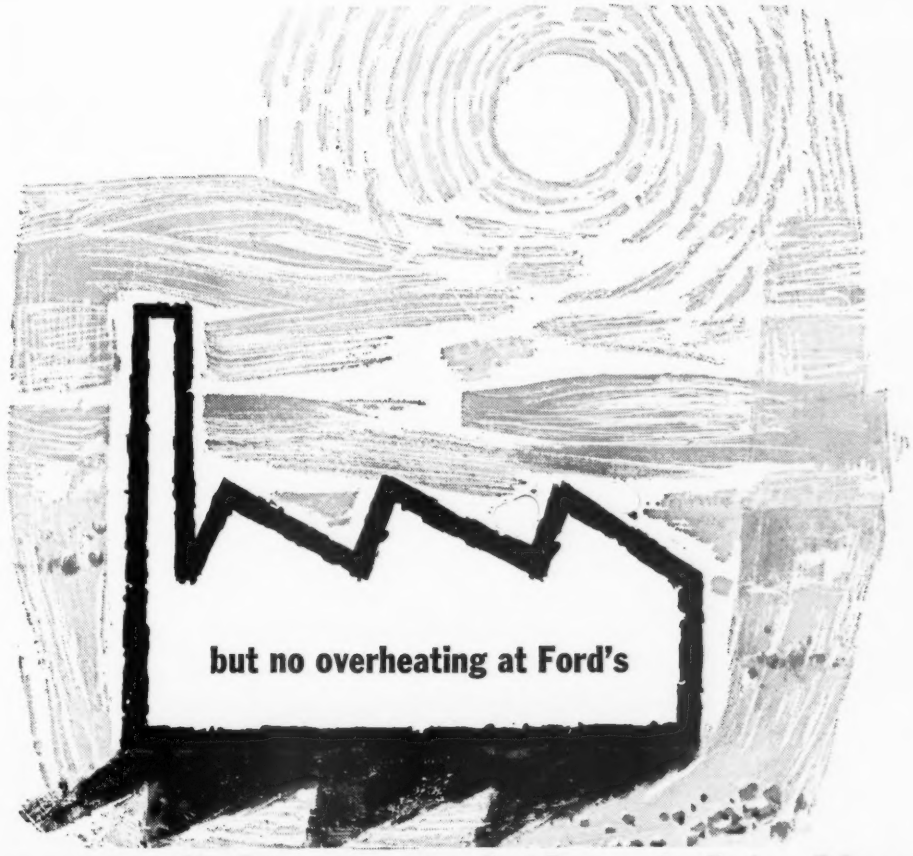

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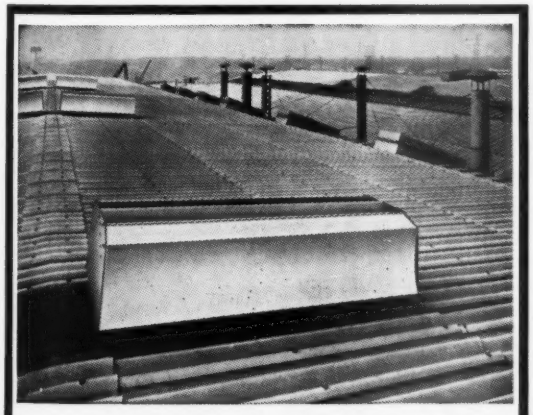

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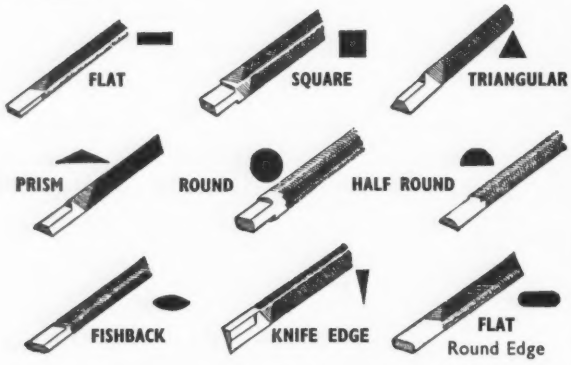

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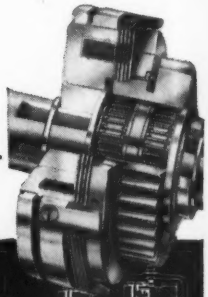

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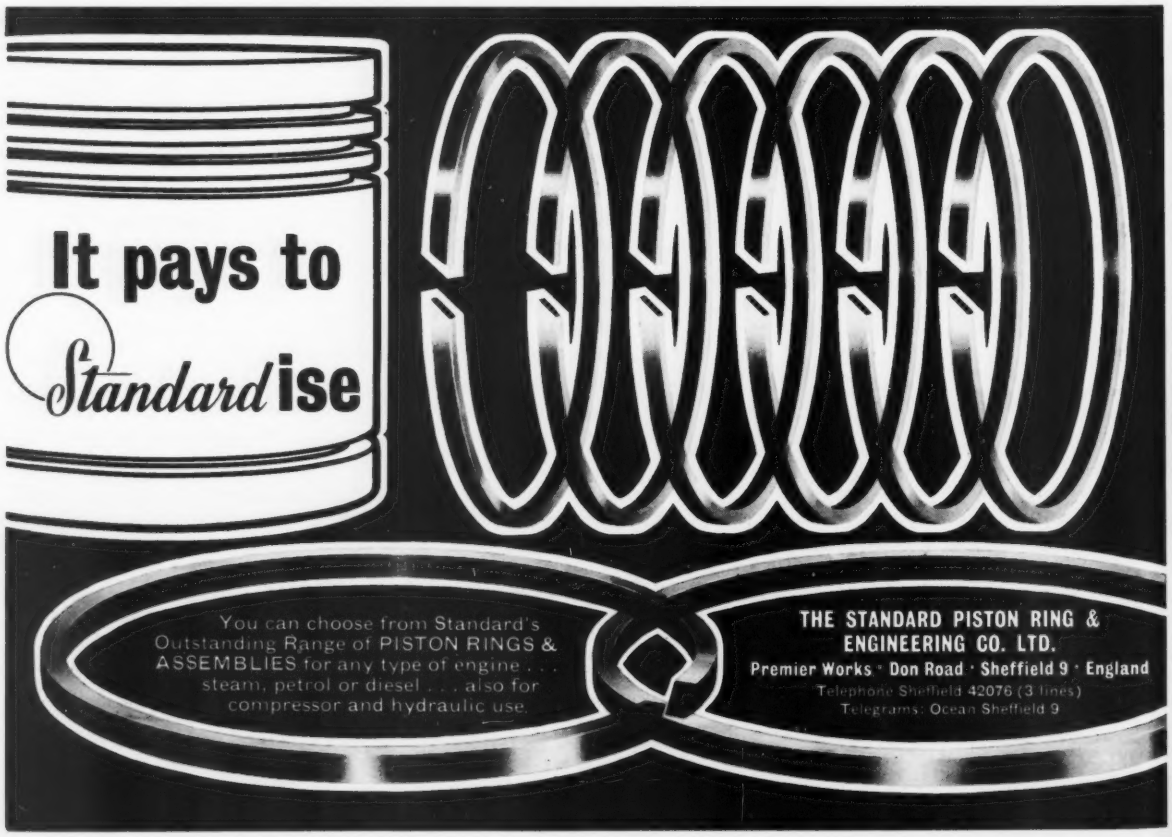
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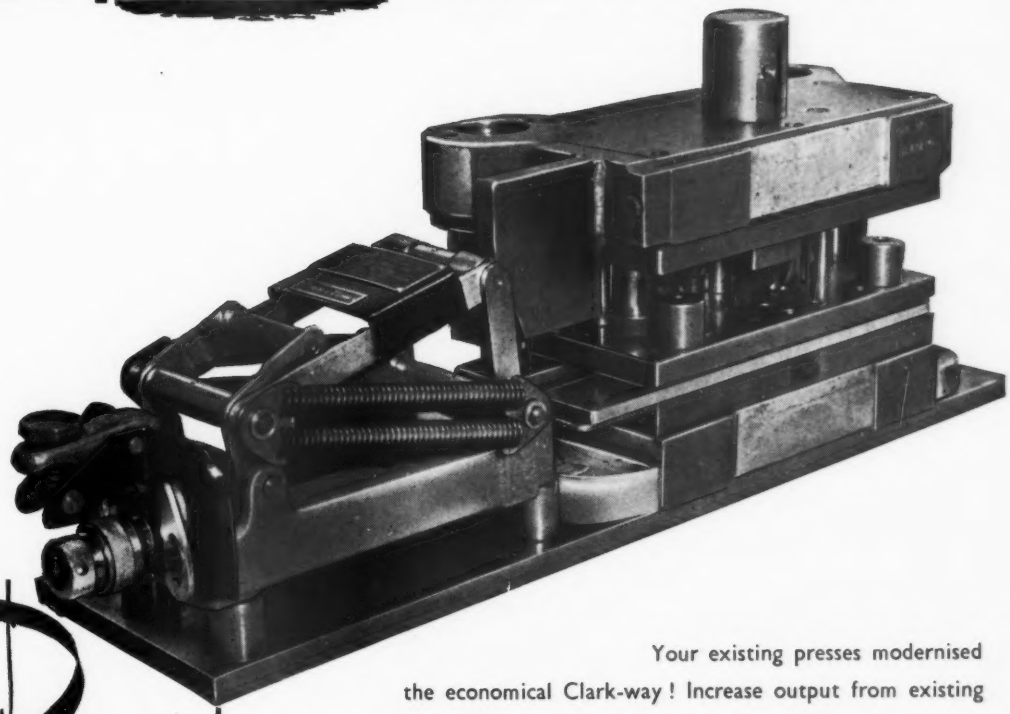

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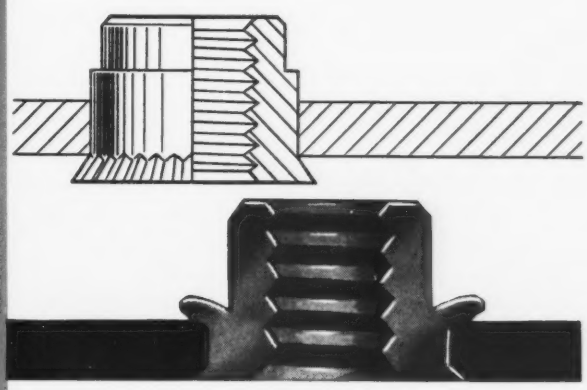

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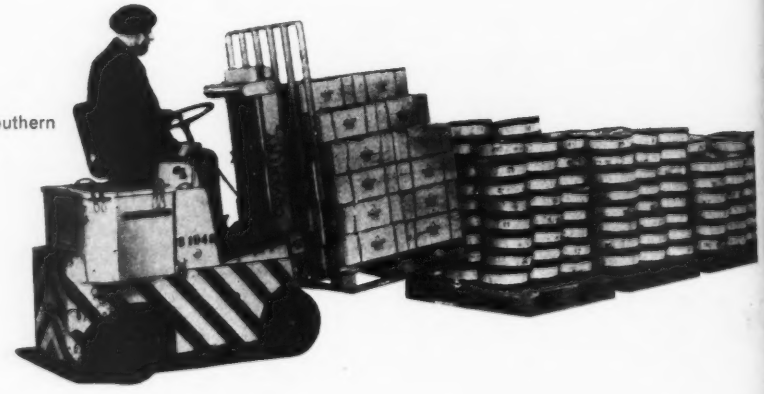

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